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THE SPACE STATION FREEDOM

BIOMEDICAL MONITORING AND COUNTERMEASURES (BMAC)

PROJECT

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FOR PUBLIC RELEASE

THE SPACE STATION FREEDOM

BIOMEDICAL MONITORING AND COUNTERMEASURES (BMAC)

PROJECT

OPERATIONALLY IMPORTANT FACTORS AFFECTING HEALTH AND PERFORMANCE DURING LONG - DURATION SSF OCCUPATION

GERALD TAYLOR, Ph.D

DECEMBER 21, 1989

OPERATIONALLY IMPORTANT FACTORS AFFECTING HEALTH AND PERFORMANCE DURING LONG - DURATION SSF OCCUPATION

MAINTENANCE GOAL	OPERATIONALLY IMPORTANT PROBLEMS
ABILITY TO PERFORM WORK	1. INCREASED MUSCULAR FATIGUE / DECREASED MUSCULAR STRENGTH 2. DECREASED ABILITY TO PERFORM LONG DURATION TASKS 3. DECREASED ABILITY TO PERFORM HIGH PRECISION TASKS 4. DECREASED ABILITY TO EMERGENCY EGRESS
NORMAL BODILY FUNCTIONS	5. SLEEP DISORDERS 6. VISUAL DYSFUNCTION 7. IMPAIRED THERMOREGULATION

BIOMEDICAL MONITORING AND COUNTERMEASURES PROGRAM

SPACE STATION FREEDOM

GERALD TAYLOR, Ph.D | DECEMBER 21, 1989

OPERATIONALLY IMPORTANT FACTORS AFFECTING HEALTH AND PERFORMANCE DURING LONG - DURATION SSF OCCUPATION

MAINTENANCE GOAL	OPERATIONALLY IMPORTANT PROBLEMS
MENTAL AND SOCIAL WELL-BEING	8. CHANGE IN MOOD / MOTIVATION 9. IMPAIRED COGNITION 10. INTERPERSONAL CONFLICT 11. PSYCHOPHYSIOLOGICAL STRESS
NORMAL BODILY STATE	12. ANEMIA 13. INFECTION 14. ALTERED PHARMACOLOGIC ACTIVITY 15. ALTERED CARDIOVASCULAR FUNCTION
NORMAL RISK LEVELS	16. RENAL STONES 17. CARDIAC DYSRHYTHMIAS 18. CANCER INDUCTION 19. OSTEOPOROSIS AND FRACTURES

GERALD TAYLOR, Ph.D

DECEMBER 21, 1989

ABILITY TO PERFORM WORK

RECOMMENDATIONS FOR MONITORING

- **MONITOR**
  - ECCENTRIC AND CONCENTRIC MUSCLE STRENGTH AT MAJOR JOINTS
  - ECCENTRIC AND CONCENTRIC MUSCLE FATIGUE AT MAJOR JOINTS
  - EMG DURING MUSCLE FUNCTION TESTING
  - BODY MASS
- **HYPOTHESIZED RESULTS AND SIGNIFICANCE**
  - DECREASED MUSCLE STRENGTH AND INCREASED MUSCULAR FATIGUE, THE MAGNITUDE OF WHICH WILL BE HIGHER IN THE LEGS, IS EXPECTED

EQUIPMENT

- ELECTROMYOGRAPH RECORDING DEVICE
- ISOKINETIC DYNAMOMETER (STRENGTH AND FATIGUE TESTING DEVICE)
- MASS MEASUREMENT DEVICE - BODY
- MULTICHANNEL DATA RECORDER

RECOMMENDATIONS FOR MONITORING

- **MONITOR**
  - OXYGEN CONSUMPTION DURING MAXIMAL UPPER BODY GRADED EXERCISE TESTING
  - ECG RESPONSE TO UPPER BODY GRADED EXERCISE TESTS
- **HYPOTHESIZED RESULTS AND SIGNIFICANCE**
  - DECREASED AEROBIC CAPACITY OF THE ARMS IS EXPECTED. THIS DECREASE WILL NOT LIKELY AFFECT MOST OPERATIONS, BUT WILL DECREASE THE ABILITY OF THE ASTRONAUTS TO COMPLETE STRENUOUS EVA AND IVA TASKS

EQUIPMENT

- ELECTROCARDIOGRAPH (HR, CARDIAC RHYTHM)
- ELECTROCARDIOGRAPH RECORDING DEVICE
- ERGOMETER - BICYCLE / ROWER (TESTING MODALITY)
- MASS SPECTROMETER - MGAS (MEASURE OF AEROBIC CAPACITY
- MULTICHANNEL DATA RECORDER

RECOMMENDATIONS FOR MONITORING

- MONITOR
  - VISUAL PURSUIT TRACKING / TARGET ACQUISITION
  - SPATIAL DISORIENTATION INDUCED BY HEAD MOVEMENTS
  - CHANGES IN LIMB POSITION SENSE, MUSCLE TONE, AND REFLEXIVE LOOP GAIN

DECREASED ABILITY TO PERFORM HIGH PRECISION TASKS

BIOMEDICAL MONITORING AND COUNTERMEASURES

Presenter:	Date:
GERALD TAYLOR / JSC	DEC. 21, 1989

- **HYPOTHESIZED RESULTS AND SIGNIFICANCE**
  - MODIFICATION OF NEUROMUSCULAR, VISUAL - VESTIBULAR, SOMATOSENSORY AND CUTANEOUS COMPONENTS COMPRISING SENSORY INPUT
  - SENSORY REARRANGEMENT WILL IMPACT HIGH PRECISION TASKS PERFORMED DURING THE TRANSITION BETWEEN G ENVIRONMENTS; THE DEGREE OF IMPACT WILL BE PROPORTIONAL TO THE DURATION OF THE MISSION

EQUIPMENT

- EOG
- ECDI
- EQUITEST POSTURE PLATFORM
- EQUITEST EQUIPMENT RACK
- GONIOMETER AND RECORDER
- VOICE ACTIVATED RECORDER
- ELECTROMYOGRAPH (EMG)
- IMPEDANCE METER
- MOTION ANALYSIS SYSTEM
- SUBJECT INTERFACE BOX
- VISUAL TRACKING SYSTEM

RECOMMENDATIONS FOR MONITORING

- MONITOR
  - MUSCLE STRENGTH AND MUSCULAR FATIGUE (BOTH ECCENTRIC AND CONCENTRIC TYPE CONTRACTIONS)
  - ESTIMATED BUFFERING CAPACITY OF BLOOD
  - ORTHOSTATIC FUNCTION (BY LBNP)
  - POSTURE AND BALANCE

Presenter: GERALD TAYLOR / JSC

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HYPOTHESIZED RESULTS AND SIGNIFICANCE

- LOSS OF MUSCLE STRENGTH
- INCREASED MUSCULAR FATIGUE
- LOWERING OF THE BUFFERING CAPACITY
- ORTHOSTATIC HYPOTENSION UPON LANDING
- POOR POSTURE AND BALANCE ON LANDING
- A COMBINATION OF THESE CHANGES WILL LEAD TO A REDUCED ABILITY TO PERFORM EMERGENCY EGRESS

EQUIPMENT

- BIOIMPEDENCE ANALYZER (FLUID STATUS)
- ELECTROCARDIOGRAPH (CARDIOVASCULAR RESPONSE TO LBNP AND EXERCISE)
- ELECTROCARDIOGRAPH RECORDING DEVICE
- ERGOMETER - BICYCLE / ROWER (ANAEROBIC POWER TESTING)
- ISOKINETIC DYNAMOMETER (STRENGTH AND FATIGUE)
- LBNP (ORTHOSTATIC INTOLERANCE)
- MASS SPECTROMETER - MGAS (NON-INVASIVE ESTIMATION OF BLOOD BUFFERING CAPACITY)
- MOTION ANALYSIS SYSTEM (BALANCE, AND GAIT ANALYSIS)
- MULTICHANNEL DATA RECORDER

NORMAL BODILY FUNCTIONS

RECOMMENDATIONS FOR MONITORING

- MONITOR
  - EKG, EEG, EMG, AND EOG PATTERNS (DURING SLEEP)
  - SALIVARY CORTISOL
  - MOOD AND STRESS MEASUREMENTS
  - "DAYTIME" ACTIVITY

• HYPOTHESIZED RESULTS AND SIGNIFICANCE

- DISTURBANCES WILL BE FOUND IN TIME FOR SLEEP ONSET, QUALITY, AND QUANTITY OF SLEEP
- THESE PARAMETERS WILL VARY DURING THE MISSION (e.g., SLEEP ONSET WILL BE MORE DELAYED EARLY IN THE MISSION)
- CHANGES IN PATTERNS OF HORMONAL CONTROL WILL OCCUR
- SLEEP DISTURBANCES WILL SHOW A STRONG CORRELATION TO MOOD AND STRESS STATES

EQUIPMENT

- ELECTROCARDIOGRAPH RECORDING DEVICE
- ELECTROENCEPHALOGRAM
- ELECTROMYOGRAPH RECORDING DEVICE
- ELECTROCULOGRAPH RECORDING DEVICE
- RADIOIMMUNOASSAY
- SALIVA COLLECTION DEVICE
- WRIST ACTIVITY MONITOR

RECOMMENDATIONS FOR MONITORING

- **MONITOR**
  - INTRAOCULAR PRESSURE (TONOMETRY)
  - RETINAL PHYSIOLOGIC RESPONSES TO SPACEFLIGHT
  - VISUAL PERFORMANCE - I.E., VISUAL ACUITY, CONTRAST SENSITIVITY, STEREOPSIS
- **HYPOTHESIZED RESULTS AND SIGNIFICANCE**
  - INCREASE IN INTRAOCULAR PRESSURE INFLIGHT, WHICH IF UNTREATED COULD LEAD TO PERMANENT LOSS OF VISION SECONDARY TO OCULAR PATHOLOGIES, e.g., GLAUCOMA AND RETINAL VASCULAR DISEASE
  - DECREMENT IN CONTRAST SENSITIVITY AND / OR NEAR VISION ACUITY

VISUAL DYSFUNCTION

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Date:
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EQUIPMENT

- FUNDUS CAMERA
- TONOPEN
- VISUAL FUNCTION TESTER

RECOMMENDATIONS FOR MONITORING

- MONITOR
  - AMBIENT TEMPERATURE AND HUMIDITY
  - AIR FLOW THROUGH THE EXERCISE FACILITY
  - CORE TEMPERATURE RESPONSE TO A LONG (1 HOUR) EXERCISE BOUT
  - ASTRONAUTS THERMAL RESPONSES DURING EVA
  - CHANGES IN BODY MASS DUE TO EVA AND EXERCISE (CRUDE ESTIMATE OF SWEAT PRODUCTION)

- **HYPOTHESIZED RESULTS AND SIGNIFICANCE**

  - THE PHYSIOLOGICAL MECHANISMS USED TO DISSIPATE HEAT WILL BE INHIBITED. MONITORING WILL ALLOW IMPLEMENTATION OF APPROPRIATE COUNTERMEASURES TO REDUCE THE MAGNITUDE OF THESE CHANGES

EQUIPMENT

- ELECTROCARDIOGRAPH (CARDIOVASCULAR RESPONSE TO EXERCISE)
- ELECTROCARDIOGRAPH RECORDING DEVICE
- MASS MEASURING DEVICE - BODY (SWEAT PRODUCTION)
- MASS SPECTROMETER - MGAS (QUANTIFICATION OF KCAL PRODUCED DURING EXERCISE TESTING)
- MULTICHANNEL DATA RECORDER
- TELETHERMOMETER - RECTAL PROBE (MEASUREMENT OF CORE TEMPERATURE)

MENTAL AND SOCIAL

WELL-BEING

RECOMMENDATIONS FOR MONITORING

- MONITOR
  - RESPONSES TO MOOD SURVEY ON CREW DEBRIEF SOFTWARE (MOOD) - OBTRUSIVE
  - VOICE STRESS (MOOD) - UNOBTRUSIVE
  - TASK SAMPLING (MOTIVATION)
  - PRODUCTIVITY TRACKING (MOTIVATION)
  - RESPONSES TO STRUCTURED INTERVIEWS WITH FLIGHT SURGEON (MOOD AND MOTIVATION)
  - REGULAR FAMILY DEBRIEF (MOOD AND MOTIVATION)
  - CORRELATIONS WITH COGNITIVE WORKLOAD AND STRESS MEASURES

HYPOTHESIZED RESULTS AND SIGNIFICANCE

- IRRITABILITY WILL INCREASE AS MISSION PROGRESSES
- OPERATIONALLY RELEVANT DECLINES IN MOOD AND MOTIVATION WILL OCCUR AS THE MISSION CONTINUES

EQUIPMENT

- CREW DEBRIEF SOFTWARE (ONBOARD)
- S. S. FREEDOM AUDIO & VIDEO EQUIPMENT
- STATE ROOM COMPUTER

RECOMMENDATIONS FOR MONITORING

- **MONITOR** (VIA EMBEDDED PSYCHO - MOTOR TASKS)
  - SHORT - TERM MEMORY RECALL
  - VISUAL TRACKING ABILITY
  - PATTERN RECOGNITION ABILITY
  - REACTION TIME
- **HYPOTHESIZED RESULTS AND SIGNIFICANCE**
  - DECREMENTS WILL BE OBSERVED IN ONE OR MORE OF THE PARAMETERS MONITORED AND THE DEGREE OF DECREMENT WILL VARY WITH TIME.
  - DECREMENTS IN ANY OF THE MONITORED PARAMETERS IS INDICATIVE OF A DECREMENT IN OVERALL COGNITIVE FUNCTION

EQUIPMENT

- A COMPONENT OF THE MOTION ANALYSIS SYSTEM THAT IS AN INPUT RECORDER TO BE IMPLANTED IN ROUTINELY USED COMPUTER - CONTROLLED EQUIPMENT (e.g., RMS)
- S. S. FREEDOM AUDIO & VIDEO EQUIPMENT
- GROUP ANALYSIS SOFTWARE

RECOMMENDATIONS FOR MONITORING

- MONITOR
  - RESPONSES TO GENERIC CREW DEBRIEF SOFTWARE ONBOARD
  - RESPONSES TO STRUCTURED INTERVIEWS WITH GROUND PERSONNEL
  - REAL-TIME AUDIO CONTENT ANALYSIS
  - REPORTS OF CONFLICTS FROM CREW AND GROUND

INTERPERSONAL CONFLICT

BIOMEDICAL MONITORING
AND
COUNTERMEASURES

Presenter:	Date:
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- **HYPOTHESIZED RESULTS AND SIGNIFICANCE**
  - CONFLICT AND DECREASED CREW COHESIVENESS WILL OCCUR MORE FREQUENTLY MID-MISSION
  - MISCOMMUNICATION WILL OCCUR ACROSS CULTURES
  - MORE CONFLICTS WILL OCCUR RELATED TO ROUTINE STATION MAINTENANCE AND PERSONAL HYGIENE ISSUES THAN TO TECHNICAL ISSUES
  - THE GREATEST AMOUNT OF CONFLICT WILL OCCUR ACROSS INTERFACES OF NATIONALITY AND BETWEEN AIR AND GROUND CREWS
  - INFORMAL NORMS FOR CONFLICT MANAGEMENT WILL ARISE DURING THE MISSION
  - CREW COORDINATION AND PERFORMANCE WILL VARY ACCORDING TO THE EFFECTIVENESS OF CONFLICT MANAGEMENT NORMS

EQUIPMENT

- CREW DEBRIEF SOFTWARE
- S. S. FREEDOM AUDIO & VIDEO EQUIPMENT (TO RECORD CREW MEETINGS AS NEEDED)

RECOMMENDATIONS FOR MONITORING

- MONITOR
  - RESPONSES TO ONBOARD CREW DEBRIEF FOR STRESS ASSESSMENT AND SOURCE DETERMINATION
  - SERUM OR URINARY CORTISOL
  - CRITICAL READINESS (PRIOR TO CRITICAL WORK e.g., EVA)

PSYCHO - PHYSIOLOGICAL STRESS	BIOMEDICAL MONITORI[illegible] AND COUNTERMEASURES	
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- **HYPOTHESIZED RESULTS AND SIGNIFICANCE**
  - SUBJECTIVE REPORTS OF STRESS WILL INCREASE FROM BASELINE PRIOR TO PERFORMANCE OF CRITICAL TASKS
  - HORMONAL INDICATORS OF STRESS WILL SHOW A GENERAL TREND TOWARD INCREASED STRESS AS A FUNCTION OF FLIGHT DURATION

EQUIPMENT

- CREW DEBRIEF SOFTWARE (ONBOARD)
- STATEROOM COMPUTER
- RADIOIMMUNOASSAY
- SALIVA COLLECTION KIT
- URINE MONITORING / ANALYSIS DEVICE

NORMAL BODILY STATE

Presenter:
GERALD TAYLOR / JSC

Date:
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ANEMIA

RECOMMENDATIONS FOR MONITORING

- MONITOR
  - THE TIME COURSE AND MAGNITUDE OF THE ERYTHROCYTE LOSS IN LONG DURATION FLIGHTS
    * HEMOGLOBIN
    * ADJUSTED HEMATOCRIT
    * ERYTHROCYTE MASS
    * RETICULOCYTE COUNTS AND AGE DISTRIBUTION
    * SERUM ERYTHROPOIETIN LEVELS
    * IRON TURNOVER IN THE BLOOD
    * SERUM BILIRUBIN
    * ERYTHROCYTE SURVIVAL

ANEMIA

BIOMEDICAL MONITORING
AND
COUNTERMEASURES

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- **HYPOTHESIZED RESULTS AND SIGNIFICANCE**
  - DECREASED SERUM HEMOGLOBIN LEVELS, ADJUSTED HEMATOCRIT, AND ERYTHROCYTE MASS ARE INDICATIVE OF ERYTHROCYTE LOSS AND INCREASES THE RISK FOR ANEMIA
  - DECREASED RETICULOCYTE COUNTS AND THEIR ALTERED AGE DISTRIBUTION DEMONSTRATE SUPPRESSED BONE MARROW ERYTHROPOIESIS
  - DECREASED ERYTHROPOIETIN LEVELS IN BLOOD ARE INDICATIVE OF ABNORMAL REGULATION OF ERYTHROPOIESIS IN RESPONSE TO ERYTHROCYTE LOSS
  - INCREASED IRON TURNOVER IN THE BLOOD AND DECREASED ERYTHROCYTE SURVIVAL DEMONSTRATE ERYTHROCYTE LYSIS
  - INCREASED SERUM BILIRUBIN LEVELS IN THE BLOOD ARE INDICATIVE OF INCREASED HEMOGLOBIN METABOLISM DUE TO ERYTHROCYTE LYSIS

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ANEMIA

EQUIPMENT:

- BLOOD COLLECTION SYSTEM
- CENTRIFUGE, HEMATOCRIT
- CENTRIFUGE, REFRIGERATED
- CHEMISTRY SYSTEM (HEMOGLOBIN, BILIRUBIN)
- EXPERIMENTAL CONTROL COMPUTER SYSTEM
- FLOW CYTOMETER (RETICULOCYTES)
- FLUID HANDLING TOOLS / SYSTEM
- FREEZER (-20 DEGREES C) (STORE SERUM, ERYTHROCYTES)
- RADIATION SHIELDED LOCKER (ERYTHROPOIETIN, ERYTHROCYTE SURVIVAL, IRON TURNOVER)
- RADIOIMMUNOASSAY (ERYTHROPOIETIN)
- REFRIGERATOR (4 DEGREES C)
- RIA PREPARATION DEVICE (ERYTHROPOIETIN)
- SAMPLE PREPARATION DEVICE
- SPECIMEN LABELLING DEVICE

RECOMMENDATIONS FOR MONITORING

- MONITOR
  - THE INCIDENCE OF INFECTIOUS DISEASES AND DETERMINATION OF THE CAUSATIVE MICROBE WILL BE RECORDED BY THE ENVIRONMENTAL HEALTH FACILITY AND REPORTED TO BMAC AND HMF
  - A COMPLETE BLOOD COUNT INCLUDING A DIFFERENTIAL LEUKOCYTE COUNT OF MONOCYTES, SUBSETS OF LYMPHOCYTES (B-LYMPHOCYTES, T-LYMPHOCYTES, NK CELLS), AND GRANULOCYTES

INFECTION

- **MONITOR - Continued**
  - CELL - MEDIATED IMMUNE FUNCTIONS
    - * LYMPHOCYTE MITOGENIC RESPONSE
    - * DELAYED - TYPE HYPERSENSITIVITY REACTIONS
    - * NATURAL KILLER CYTOTOXIC ACTIVITY
    - * CYTOKINE PRODUCTION AND ACTIVITY (INTERFERON, INTERLEUKIN 2)
    - * NEUTROPHIL AND MONOCYTE FUNCTIONS
    - * ANTIBODY PRODUCTION TO COMMON ANTIGENS

- **HYPOTHESIZED RESULTS AND SIGNIFICANCE**

  - AN INCREASED INCIDENCE OF INFECTIONS WILL NECESSITATE THE USE OF PROPHYLAXIS WITH ANTIBIOTICS AND THE REPLACEMENT OF NORMAL FLORA ORGANISMS SUCH AS LACTOBACILLI
  - THE DEVELOPMENT OF ABNORMAL LEUKOCYTE DIFFERENTIALS AND / OR ABSOLUTE COUNTS ARE INDICATIVE OF INFECTIONS AND / OR SUPPRESSED IMMUNITY DURING SPACEFLIGHT
  - DECREASED CELL - MEDIATED FUNCTIONS ARE INDICATIVE OF SUPPRESSED IMMUNOCOMPETENCE OF THE FLIGHT CREW

EQUIPMENT

- BLOOD COLLECTION SYSTEM
- CELL HANDLING ACCESSORIES
- FLUID HANDLING TOOLS / SYSTEM
- CENTRIFUGE, STANDARD LAB (SEPARATING MONONUCLEAR CELLS FROM BLOOD)
- REFRIGERATOR (4 DEGREES C) (STORE REAGENTS, SPECIMENS)
- MITOGEN CULTURE DEVICE (MITOGENIC STIMULATION, CYTOKINE PRODUCTION AND ACTIVITY [INTERFERON, INTERLEUKIN 2])
- COMPUTER SYSTEM FOR EXPERIMENTS
- CELL HARVESTER (MITOGENIC STIMULATION)
- 96-WELL PLATE WASHER / REAGENT DISPENSER
- ELISA READER (SPECIFIC ANTIBODY TITERS)
- FREEZER (-20 DEGREES C) (FREEZING SERUM AND CULTURE SUPERNATANTS)
- INCUBATOR (37 DEGREES C) (TARGET CELL TISSUE CULTURE FOR NATURAL KILLER CYTOTOXIC ACTIVITY)

INFECTION

EQUIPMENT: - Continued

- LIFE SCIENCES GLOVEBOX (MITOGENIC STIMULATION, CYTOKINE PRODUCTION AND ACTIVITY [INTERFERON INTERLEUKIN 2])
- FLOW CYTOMETER (COMPLETE BLOOD COUNT, NATURAL KILLER CYTOTOXIC ACTIVITY, NEUTROPHIL AND MONOCYTE FUNCTIONS, LEUKOCYTE DIFFERENTIAL)
- SHIELDED ISOTOPE CONTAINER (MITOGENIC STIMULATION)
- SCINTILLATION COUNTER (MITOGENIC STIMULATION)
- INCUBATOR, CENTRIFUGAL (37 DEGREES C) (MITOGENIC STIMULATION, CYTOKINE PRODUCTION AND ACTIVITY [INTERFERON INTERLEUKIN2])
- MICROSCOPE SYSTEM (LEUKOCYTE DIFFERENTIAL, MITOGENIC STIMULATION, BACK-UP TO THE CYTOMETER)

RECOMMENDATIONS FOR MONITORING

- **MONITOR**
  - DEVIATIONS FROM NORMAL GI AND HEPATIC FUNCTION
  - POTENTIALLY HAZARDOUS DRUG REACTIONS
  - DEVIATIONS IN NORMAL PHARMACOLOGIC REACTIONS FROM COMMONLY USED DRUGS (i.e., PLASMA DRUG LEVELS OVER SPECIFIED TIME PERIODS)
- **HYPOTHESIZED RESULTS AND SIGNIFICANCE**
  - CHANGES IN GASTRIC AND / OR HEPATIC FUNCTION COUPLED WITH REDUCED EFFICACY OF SPECIFIED, COMMONLY USED PHARMACEUTICALS ARE EXPECTED

EQUIPMENT

- HPLC
- RADIOIMMUNOASSAY
- CENTRIFUGE, REFRIGERATED
- MODEL 12 MICROLYZER
- HEIDELBERG pH CAPSULE SYSTEM
- URINE MONITORING / ANALYSIS DEVICE
- BLOOD COLLECTION SYSTEM
- SALIVA COLLECTION DEVICE
- CHEMISTRY SYSTEM
- SPECIMEN LABELING DEVICE

RECOMMENDATIONS FOR MONITORING

- MONITOR
  - HEMATOCRIT, BODY MASS, AND PLASMA VOLUME
  - HEART RATE AND BLOOD PRESSURE RESPONSE DURING LBNP
  - BARORECEPTOR FUNCTION
  - CENTRAL CARDIAC FUNCTION (STRUCTURES AND BLOOD FLOW VELOCITIES)
  - CARDIAC OUTPUT
  - PERIPHERAL VASCULAR CONTROL
  - LOSS OF SKELETAL MUSCLE TONE IN THE LEGS

ALTERED CARDIOVASCULAR FUNCTION

BIOMEDICAL MONITORI[NG] AND COUNTERMEASURES	
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- **HYPOTHESIZED RESULTS AND SIGNIFICANCE**
  - DECREASE IN CARDIAC MASS
  - RELATIVE HYPOVOLEMIA
  - ALTERED BARORECEPTOR FUNCTION
  - INCREASED COMPLIANCE OF THE VASCULAR TISSUE
  - NEUROENDOCRINE CHANGES
  - THESE CHANGES WILL RESULT IN THE INDUCEMENT OF ORTHOSTATIC INTOLERANCE UPON RETURN TO GRAVITY, AND MAY ALSO EFFECT THE ABILITY TO PERFORM STRENUOUS CARDIOVASCULAR WORK (DURING EVA AND POSSIBLY EGRESS)

EQUIPMENT

- BIOIMPEDENCE ANALYZER (CENTRAL CARDIAC FUNCTION)
- BLOOD COLLECTION SYSTEM
- BLOOD FLOW AND PLETHSMOGRAPH SYSTEM (HYPOVOLEMIA AND MUSCLE TONE)
- BLOOD PRESSURE INSTRUMENTATION (AUTONOMIC FUNCTION)
- CAROTID SINUS BARORECEPTOR STIMULATOR (AUTONOMIC DYSFUNCTION)
- ECHOCARDIOGRAPH / DOPPLER VELOCIMETER (CENTRAL CARDIAC FUNCTION)
- ELECTROCARDIOGRAPH (HEART RATE AND RHYTHM DURING LBNP AND EXERCISE)
- ELECTROCARDIOGRAPH RECORDING DEVICE

EQUIPMENT - Continued

- HEMATOCRIT CENTRIFUGE
- ISOKINETIC DYNAMOMETER (LEG STRENGTH)
- LBNP (ORTHOSTATIC STRESSOR
- MASS MEASURING DEVICE - BODY (HYPOVOLEMIA)

NORMAL RISK LEVELS

RENAL STONES

Presenter:
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RECOMMENDATIONS FOR MONITORING

- MONITOR
  - CONCENTRATION OF STONE FORMING SALTS IN THE URINE
  - URINE OSMOLALITY, VOLUME, SPECIFIC GRAVITY, AND pH
- HYPOTHESIZED RESULTS AND SIGNIFICANCE
  - INCREASED URINARY SALTS, SPECIFIC GRAVITY, AND ACIDITY COUPLED WITH DECREASED URINE VOLUME ARE TRENDS WE EXPECT TO ENCOUNTER.

EQUIPMENT

- ION CHROMATOGRAPH
- CHEMISTRY SYSTEM
- pH METER / ION SPECIFIC ANALYZER
- URINE MONITORING / ANALYSIS DEVICE
- OSMOMETER
- SPECIMEN LABELING DEVICE

RECOMMENDATIONS FOR MONITORING

- MONITOR
  - CARDIAC RHYTHM DURING REST, EXERCISE, AND LBNP
  - SERUM ELECTROLYTES (POTASSIUM IS OF PARTICULAR IMPORTANCE)
  - AUTONOMIC FUNCTION
- HYPOTHESIZED RESULTS AND SIGNIFICANCE
  - CARDIAC RHYTHM WILL NOT ALTER DANGEROULSY IN MOST CREWMEMBERS; HOWEVER, CLINICALLY SIGNIFICANT DYSRYTHMIAS WILL OCCUR IN SOME.

EQUIPMENT

- BLOOD PRESSURE INSTRUMENTATION (AUTONOMIC FUNCTION)
- CAROTID SINUS BARORECEPTOR STIMULATOR (AUTONOMIC DYSFUNCTION)
- ELECTROCARDIOGRAPH (HEART RATE AND RHYTHM TO LBNP AND EXERCISE)
- ELECTROCARDIOGRAPH RECORDING DEVICE
- ION CHROMATOGRAPH (ELECTROLYTE STATUS)
- LBNP (ORTHOSTATIC STRESSOR)
- MASS MEASURING DEVICE - BODY (HYPOVOLEMIA)

RECOMMENDATIONS FOR MONITORING

- **MONITOR**
  - RADIATION EXPOSURE LEVELS WILL BE RECORDED BY THE ENVIRONMENTAL HEALTH FACILITY AND REPORTED TO BMAC AND HMF
  - GENETIC ABNORMALITIES OF MITOGEN - STIMULATED BLOOD LYMPHOCYTES
    - * CHROMOSOMAL ABERRATIONS
    - * ONCOGENE PRODUCTS
    - * DNA SYNTHESIS (REPAIR)
  - NATURAL KILLER CYTOTOXIC FUNCTION

CANCER INDUCTION

BIOMEDICAL MONITORING AND COUNTERMEASURES

Presenter: GERALD TAYLOR / JSC

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- **HYPOTHESIZED RESULTS AND SIGNIFICANCE**
  - RADIATION EXPOSURE ABOVE ACCEPTABLE LIMITS MAY INCREASE THE RISK OF CANCER
  - INCREASED NUMBER OF CHROMOSOMAL ABERRATIONS, ONCOGENE PRODUCTS, AND DNA SYNTHESIS (REPAIR) IN MITOGEN - STIMULATED BLOOD LYMPHOCYTES ARE INDICATIVE OF RADIATION DAMAGE AT THE CELLULAR LEVEL THAT MAY INCREASE THE RISK OF CANCER
  - SUPPRESSED NATURAL KILLER CYTOTOXIC FUNCTION IS INDICATIVE OF RADIATION DAMAGE AND/OR ATTENUATED IMMUNITY DURING SPACEFLIGHT AND MAY INCREASE THE RISK OF CANCER

CANCER INDUCTION

Presenter:
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Date:
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EQUIPMENT

- BLOOD COLLECTION SYSTEM
- CELL HANDLING ACCESSORIES
- CENTRIFUGE, REFRIGERATED (SEPARATE BLOOD CELLS)
- EXPERIMENTAL CONTROL COMPUTER SYSTEM
- FLOW CYTOMETER (NATURAL KILLER CYTOTOXIC ACTIVITY, ONCOGENE PRODUCTS, DNA SYNTHESIS [REPAIR])
- FLUID HANDLING TOOLS / SYSTEM
- IMAGE DIGITIZING SYSTEM (CHROMOSOMAL ABERRATIONS)
- INCUBATORS CENTRIFUGAL (2) (MITOGEN STIMULATION)
- INCUBATOR (37 DEGREES C) (TARGET TUMOR TISSUE CULTURE)
- LIFE SCIENCES GLOVE BOX (MITOGEN STIMULATION)
- MICROSCOPE SYSTEM (CHROMOSOMAL ABERRATIONS)
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EQUIPMENT - Continued

- MITOGEN CULTURE DEVICE (MITOGEN STIMULATION)
- REFRIGERATOR (4 DEGREES C) (STORE REAGENTS)
- SAMPLE PREPARATION DEVICE
- SLIDE PREPARATION DEVICE
- SPECIMEN LABELLING DEVICE

RECOMMENDATIONS FOR MONITORING

- **MONITOR**
  - PATTERNS AND RATE OF BONE LOSS
  - CALCIUM HOMEOSTASIS
  - REVERSIBILITY OF BONE DEMINERALIZATION
- **HYPOTHESIZED RESULTS AND SIGNIFICANCE**
  - EVIDENCE OF BONE DEMINERALIZATION IN WEIGHT-BEARING BONES AND CHANGES IN PLASMA AND URINE ELECTROLYTE LEVELS AND FECAL CALCIUM
  - BONE DEMINERALIZATION DURING MICROGRAVITY MAY BE IRREVERSIBLE

EQUIPMENT

- HARD TISSUE IMAGER
- PASSIVE DOSIMETER
- DRUG ADMINISTRATION EQUIPMENT
- DEVICE TO SIMULATE WEIGHT-BEARING EXERCISE
- ION CHROMATOGRAPH
- SPECIMEN LABELING TOOLS/DEVICE
- URINE MONITORING SYSTEM
- BLOOD COLLECTION SYSTEM
- FLUID HANDLING TOOLS/SYSTEM
- RIA PREP DEVICE
- RIA
- HPLC
- FECAL MONITORING SYSTEM
- LIFE SCIENCES GLOVEBOX
- CHEMISTRY SYSTEM
- CENTRIFUGE, REFRIGERATED
- FREEZE DRYER
- FREEZER

EQUIPMENT - Continued

- LAB SCIENCES WORKBENCH
- MASS MEASUREMENT DEVICE-SMALL
- pH METER/ION SPECIFIC ANALYZER
- RADIATION SHIELDED LOCKER
- SAMPLE PREP. DEVICE
- SCINTILLATION COUNTER
- SPECTROPHOTOMETER (UV/VIS/INR)
- TREADMILL

THE
SPACE STATION FREEDOM

BIOMEDICAL MONITORING
AND
COUNTERMEASURES
(BMAC)

PROJECT

EQUIPMENT DEFINITIONS

BMAC EQUIPMENT DEFINITIONS
February 9, 1989 2:30 P.M.

Bioimpedance Analyzer: Can be used to estimate beat by beat changes in stroke volume and provide an estimate of cardiac output. The bioimpedance analyzer also can be used to determine lean body mass.

Blood Collection System: Equipment for the routine sampling of blood.

Blood Flow and Plethysmography System: The peripheral Doppler velocimeter will allow quantification of peripheral blood flow. The plethysmograph portion of the system is used to detect changes in limb volume, hypovolemia (fluid status), changes in muscle tone, and peripheral blood flow.

Blood Pressure Instrumentation: The blood pressure device is used for the non-invasive measurement of both systolic and diastolic blood pressures.

Carotid Sinus Baroreceptor Stimulator: This device stimulates the pressure receptors located in the carotid sinus and is used to test autonomic dysfunction. Pressure applied above the carotid sinus should cause a reflex bradycardia.

Cell Handling Accessories: Tools used to transfer cells from specimens to microscope slides in a microgravity environment.

Cell Harvester: Equipment for harvesting tritium labelled leukocytes for the mitogenic stimulation assay which measures immune function.

Centrifuge, Hematocrit: Equipment for determining relative erythrocyte mass.

Centrifuge, Refrigerated: Device for separating various biological samples by gradient centrifugation in a temperature controlled environment.

Chemistry System: An instrument used to determine the levels of compounds in blood and urine (e.g. urea, glucose, calcium, bilirubin, hemoglobin, etc.).

Controlled Testing Unit: A set of equipment to be used in conjunction with various pieces of experimental equipment for the procedures of set-up, storage, containment, manipulation, etc.

Crew Debrief/Analysis Software: Used to determine and analyze crew behavior in terms of changing mood/motivation patterns and interpersonal conflict.

Drug Administration Equipment: Equipment to be used for pharmocologic intervention in the treatment of bone demineralization.

Echocardiogram/Doppler Velocimeter: The structures of the heart, cardiac dimensions and ejection fraction can be determined using 2D Echo. The flow of blood through the valves, aorta, and pulmonary trunk can be measured with a Doppler velocimeter. Cardiac output determinations can be performed with these devices .

Echocardiograph Recording Device: This device is used for the determination of heart rate and rhythm and will be used during the cardiovascular and exercise experiments.

Electoencephalogram: Used to monitor astronauts brain wave activity during a wide range of activities.

Electromyograph Recording Device: This device detects the electrical activity of a skeletal muscle during contraction.

Electro-oculograph Recording Device: A device to monitor the electrical activity of the muscles controlling eye movement. This will be used to correlate vestibular function with task performance.

ELISA Reader: Instrument for quantifying the levels of erythropoietin or specific antibodies in serum for each well of an ELISA plate.

Equi-Test Posture Platform: Presents subject with random perturbations as a part of movement coordination testing.

Equi-Test Instrumentation Racks: Controls posture platform, performs data acquisition, and amplifies incoming electrical signals.

Ergometer: The bicycle ergometer will be used as the exercise modality during graded exercise testing to determine both the aerobic capacity and anaerobic power of an individual.

Experiment Control Computer System: Computer System to process and store all data related to the life science experiments.

Experiment Control Data Interface: This equipment performs acquisition, formatting and transmission of data from vestibular studies.

Fecal Monitoring System: Provides for fecal collection and measurement, and allows for sample extraction; to be used for measuring calcium balance and absorption.

Flow Cytometer: Instrument for measuring the number of blood cells, and leukocyte functions.

Fluid Handling Tools/System: System for supplying the necessary fluids to equipment, recovering reusable fluid, and disposing/storing of biohazardous fluids.

Freeze Dryer: Used to preserve samples from calcium balance studies for ground-based analysis.

Freezer (-20° C): Stores serum, urine, blood, and reagents for long periods of time.

Freezer (-70° C): Used to freeze samples from calcium balance studies for ground-based analysis.

Fundus Camera: A hand-held instrument used in examining the fundus region of the retina for physiological responses to spaceflight and vascular disease.

Goniometer and Recorder: An instrument used to measure the range of motion of joints (angles) of crew members in microgravity.

Hard Tissue Imager: A measurement device to monitor patterns and rate of bone loss inflight.

Heidelberg pH Capsule System: A frequency modulated, radio signal measuring receiver with meter and recorder used for monitoring gastrointestinal physiology in terms of pH.

HPLC: Separates and identifies components of biological samples for evaluation.

Image Digitizing System: Examines the morphology of cells and subcellular components in blood cells along with the microscope system.

Impedance Meter: A device used to insure low impedance when measuring bio-electrical impulses.

Incubator(37^{o} C): Equipment for growing tissue culture cells.

Incubators, Centrifugal (2): Equipment for the mitogenic stimulation assay simulating a 1g environment in space.

Ion Chromatograph: An instrument used to measure both anion and cation contaminants in urine, as well as to determining serum potassium levels during flight.

Isokinetic Dynamometer: The isokinetic dynamometer is used to quantify strength and fatigue changes.

Lab Sciences Workbench: A bench where samples not requiring bioisolation can be prepared for storage or analysis; will be used in calcium balance studies.

LBNP: The LBNP device is used for testing orthostatic responses by inducing fluid shifts to the lower extremities and may be potentially used as a countermeasure for orthostatic intolerance.

Life Sciences Glovebox: Provides an isolated environment for aseptic handling and transferring blood cells and tissue cultures.

Mass Measurement Device (body): Used to determine the mass of subjects in microgravity. The device will assist in providing data to quantify degree of hypovolemia, sweat loss during exercise, and lean body mass changes.

Mass Measurement Device (small): Will be used to measure specimens in the range of 1 mg. to 10 kg. in microgravity such as vomitus and uneaten food in calcium balance studies.

Mass Spectrometer (MGAS): The MGAS is used to determine the aerobic work capacity of an individual. Data collected during a graded exercise test with the MGAS can provide a non-invasive estimate of blood buffering capacity.

Microscope System: Examines the morphology of human cells and subcellular components in conjunction with the image digitizing system.

Mitogen Culture Device: An enclosed device which dispenses cells, mitogens, or media into the appropriate wells of a culture plate.

Model 12 Microlyzer: Breath hydrogen analyzer used to measure gastrointestinal transit times.

Motion Analysis System: The motion analysis device will provide data on locomotor patterns primarily during treadmill exercise, as well as providing information during posture studies. This data may also be useful in determination of the ability to rapidly egress. This system also includes monitors for accumulating data in terms of dextrous manipulation of commonly used items, i.e. joysticks, tuning controls, etc.

Multichannel Data Recorder: Used to collect and record signals generated by the ECG, EEG, EMG, and other analysis equipment.

Osmometer: Device used to measure the osmolality of urine samples.

Passive Dosimeter: A device used to measure exposure to radiation which will be required if tomography is used to measure bone density.

pH Meter/Ion Specific Analyzer: An instrument used to measure the acid-base status of the urine.

Radiation Shielded Locker: Stores and holds all radioactive materials used for labelling specimens.

Radioimmunoassay: A device in which hormones, antigens, antibodies, drugs, and other substances occurring in minute quantities are measured using radioisotopes.

Refrigerator (4° C): Stores samples and reagents for short periods of time.

RIA Preparation Device: A device which would prepare blood or urine samples for use in conjunction with the radioimmunoassay.

Saliva Collection Device: A device to safely collect human saliva specimens.

Sample Preparation Device: Instrument for processing various biological samples (blood, urine, saliva) for further downstream analysis.

Scintillation Counter: Measures the radioactivity of samples labelled with radioisotopes emitting bets radiation such as tritium.

Slide Preparation Device: A device which prepares blood samples on a slide for viewing with the microscope.

Space Station Audio and Video Equipment: Used to record crew meetings and/or crew operations during spaceflight. This also provides the capability of private downlink time between crew persons and ground based individuals.

Specimen Labelling Device: A device capable of labelling containers and specimens, which can then be automatically read and entered into a database which contains all of the information pertaining to that particular sample or specimen.

Spectrophotometer(UV/VIS/INR): Equipment used to measure light-absorbing components in solution.

Subject Interface Box: Conditions EOG, accelerator, goniometer and video signals, and transmits them to the ECDI during vestibular studies.

Telethermometer/Rectal Probe: The telethermometer is used to obtain measurements of core temperature.

Tonometer: An instrument used to monitor changes in intraocular pressure.

Treadmill: Will be used to simulate weight-bearing exercise to ameliorate bone demineralization.

Urine Monitoring/Analysis Device: Provides for the collection, volume measurement, and sampling of individual micturations, as well as some chemical analyses.

Visual Function Testers: Designed to test several parameters of human vision including visual acuity, muscle balance, retinal rivalry, contrast threshold and target accommodation.

Visual Tracking System: Provides a controlled stimulus for eye movements during vestibular studies.

Voice Recorder: Used to record subjective perception of motion during voluntary head movements on orbit.

Wrist Activity Monitor: Needed to monitor patterns in limb motion during prolonged periods in microgravity.

THE
SPACE STATION FREEDOM

BIOMEDICAL MONITORING
AND
COUNTERMEASURES
(BMAC)

PROJECT

SPACE & LIFE SCIENCES

JSC

EQUIPMENT REQUIREMENTS
AND
SPECIFICATIONS

PRELIMINARY BMAC EQUIPMENT REQUIREMENTS

2/9/90 11:30 A.M.

Equipment Name

Bioimpedance Analyzer
Blood Collection System
Blood Flow and Plethysmography System
Blood Pressure Instrumentation
Carotid Sinus Baroreceptor Stimulator
Cell Handling Accessories
Cell Harvester
Centrifuge, Hematocrit
Centrifuge, Refrigerated
Chemistry System
Controlled Testing Units
Crew Debrief/Group Analysis Software
Drug Administration Equipment
Echocardiograph/Doppler Velocimeter
Electrocardiograph Recording Device
Electroencephalogram
Electromyograph Recording Device
Electro-oculograph Recording Device
ELISA Reader
Equi-Test Posture Platform
Equi-Test Instrumentation Rack
Ergometer (bicycle/rower)
Experiment Control Computer System
Experiment Control Data Interface
Fecal Monitoring System
Flow Cytometer
Fluid Handling Tools/System
Freeze Dryer
Freezers (-20 °C)
Freezers (-70 °C)
Fundus Camera
Goniometer and Recorder
Hard Tissue Imager
Heidelberg pH Capsule System
HPLC
Image Digitizing System
Impedance Meter
Incubator (37 °C)
Incubators, Centrifugal (2)
Ion Chromatograph
Isokinetic Dynamometer
Lab Sciences Workbench
LBNP
Life Sciences Glovebox
Mass Measurement Device (Body)
Mass Measurement Device (Small)
Mass Spectrometer (MGAS)
Microscope System
Mitogen Culture Device
Model 12 Microlyzer
Motion Analysis System
Multichannel Data Recorder
Osmometer
Passive Dosimeter
pH Meter/Ion Specific Analyzer
Radiation Shielded Locker
Radioimmunoassay
Refrigerator (4 °C)
RIA Preparation Device
Saliva Collection Device
Sample Preparation Device
Scintillation Counter
Slide Preparation Device
S.S. Freedom Audio & Video Equipment
Specimen Labelling Device
Spectrophotometer
Subject Interface Box
Telethermometer/ Rectal Probe
Tonometer
Treadmill
Urine Monitoring/Analysis Device
Visual Function Testers (I, II, III)
Visual Tracking System
Voice Recorder
Wrist Activity Monitor

NUMBER OF ITEMS: 75

Equipment Name	Mass (kilograms)	Volume (cubic meters)	Power (kilowatts)
Bioimpedance Analyzer	4.54	0.005	0.002
Blood Collection System	21.60	0.010	none
Blood Flow and Plethysmography System	25.00	0.042	0.090
Blood Pressure Instrumentation	15.50	0.022	0.200
Carotid Sinus Baroreceptor Stimulator	45.30	0.124	0.225
Cell Handling Accessories	1.00	0.010	none
Cell Harvester	29.00	0.042	0.050
Centrifuge, Hematocrit	0.83	0.001	batteries
Centrifuge, Refrigerated	26.00	0.092	0.200
Chemistry System	23.00	0.093	0.100
Controlled Testing Units	109.80	0.525	0.000
Crew Debrief/Analysis Software	none	none	none
Drug Administration Equipment	1.00	0.005	none
Echocardiograph/Doppler Velocimeter	70.00	0.200	0.600
Electrocardiograph Recording Device	8.50	0.008	0.100
Electroencephalogram	1.30	0.005	none
Electromyograph Recording Device	2.00	0.007	0.020
Electro-oculograph Recording Device	2.00	0.007	0.020
ELISA Reader	6.00	0.200	0.100
Equi-Test Posture Platform	ground	ground	ground
Equi-Test Instrumentation Racks	ground	ground	ground
Ergometer (Bicycle/Rower)	56.70	0.425	0.025
Experiment Control Computer System	67.00	0.278	0.250
Experiment Control Data Interface	33.82	0.037	0.560
Fecal Monitoring System	25.00	0.118	0.050
Flow Cytometer	36.00	0.235	0.500
Fluid Handling Tools/System	80.00	0.480	0.100
Freeze Dryer	19.00	0.067	0.140
Freezer (-20 degrees centigrade)	120.00	0.480	0.300
Freezer (-70 degrees centigrade)	120.00	0.480	0.300
Fundus Camera	2.00	0.003	0.000
Goniometer and Recorder	2.40	0.007	0.025
Hard Tissue Imager	ground	ground	ground
Heidelberg pH Capsule System	12.80	0.015	0.070
HPLC	40.00	0.120	0.100
Image Digitizing System	31.00	0.094	0.500
Impedance Meter	0.82	0.004	none
Incubator (37 degrees centigrade)	50.00	0.160	0.400
Incubators, Centrifugal (2)	80.00	0.320	0.600
Ion Chromatograph	31.00	0.097	0.480
Isokinetic Dynamometer	84.82	0.479	1.100
Lab Sciences Workbench	350.00	0.960	0.800
LBNP	20.00	0.150	0.060
Life Sciences Glovebox	350.00	0.960	0.800
Mass Measurement Device (Body)	34.50	0.651	0.020
Mass Measurement Device (Small)	17.00	0.080	0.015
Mass Spectrometer (MGAS)	40.70	0.086	0.150
Microscope System	100.00	0.400	0.400
Mitogen Culture Device	2.00	0.007	0.150
Model12 Microlyzer	7.30	0.018	0.112
Motion Analysis System	8.70	0.010	batteries
Multichannel Data Recorder	20.00	0.073	0.060
Osmometer	5.40	0.016	0.020
Passive Dosimeter	35.00	0.085	none
pH Meter/Ion Specific Analyzer	7.00	0.004	batteries
Radiation Shielded Locker	80.00	0.200	0.000
Radioimmunoassay	20.00	0.053	none
Refrigerator (4 degrees centigrade)	40.00	0.150	0.450
RIA Preparation Device	2.00	0.007	none
Saliva Collection Device	0.17	0.001	none
Sample Preparation Device (4 parts)	32.40	0.243	0.150
Scintillation Counter	ground	ground	ground
Slide Preparation Device	2.00	0.007	0.020
Space Station Audio & Video Equipment	no cost to BMAC	no cost to BMAC	no cost to BMAC
Specimen Labelling Device	4.00	0.010	0.020
Spectrophotometer	40.00	0.110	0.300
Subject Interface Box	4.33	0.018	none
Telethermometer	15.00	0.019	0.014
Tonometer	0.06	0.001	none
Treadmill	82.55	0.450	0.500
Urine Monitoring/Analysis System	90.00	0.300	0.200
Visual Function Testers (I,II,III)	8.80	0.120	batteries
Visual Tracking System	1.77	0.012	none
Voice Recorder	0.20	0.001	none
Wrist Activity Monitor	0.10	0.001	batteries
Totals	2703.71	10.500	11.448

2/14/90

Mass, Power, Volume and Development Program for BMAC used Equipment

Equipment Name	Mass (kilograms)	Volume (cubic meters)	Power (kilowatts)	Development Program
Bioimpedance Analyzer	4.54	0.005	0.002	ECF
Blood Collection System	21.60	0.010	none	BMAC
Blood Flow and Plethysmography System	25.00	0.042	0.090	BMAC
Blood Pressure Instrumentation	15.50	0.022	0.200	BMAC
Carotid Sinus Baroreceptor Stimulator	45.30	0.124	0.225	BMAC
Cell Handling Accessories	1.00	0.010	none	BMAC
Cell Harvester	29.00	0.042	0.050	BMAC
Centrifuge, Hematocrit	0.83	0.001	batteries	BMAC
Centrifuge, Refrigerated	26.00	0.092	0.200	BMAC
Chemistry System	23.00	0.093	0.100	HMF
Controlled Testing Units	109.80	0.525	0.000	BMAC
Crew Debrief/Analysis Software	none	none	none	BMAC
Drug Administration Equipment	1.00	0.005	none	HMF
Echocardiograph/Doppler Velocimeter	70.00	0.200	0.600	WP-01
Electrocardiograph Recording Device	8.50	0.008	0.100	ECF
Electroencephalogram	1.30	0.005	none	BMAC
Electromyograph Recording Device	2.00	0.007	0.020	BMAC
Electro-oculograph Recording Device	2.00	0.007	0.020	BMAC
ELISA Reader	6.00	0.200	0.100	BMAC
Equi-Test Posture Platform	ground	ground	ground	EDO
Equi-Test Instrumentation Racks	ground	ground	ground	EDO
Ergometer (Bicycle/Rower)	56.70	0.425	0.025	ECF
Experiment Control Computer System	67.00	0.278	0.250	BMAC
Experiment Control Data Interface	33.82	0.037	0.560	IML-1
Fecal Monitoring System	25.00	0.118	0.050	BMAC
Flow Cytometer	36.00	0.235	0.500	BMAC
Fluid Handling Tools/System	80.00	0.480	0.100	WP-01
Freeze Dryer	19.00	0.067	0.140	WP-01
Freezer (-20 degrees centigrade)	120.00	0.480	0.300	WP-01
Freezer (-70 degrees centigrade)	120.00	0.480	0.300	WP-01
Fundus Camera	2.00	0.003	0.000	BMAC
Goniometer and Recorder	2.40	0.007	0.025	BMAC
Hard Tissue Imager	ground	ground	ground	BMAC
Heidelberg pH Capsule System	12.80	0.015	0.070	BMAC
HPLC	40.00	0.120	0.100	WP-01
Image Digitizing System	31.00	0.094	0.500	BMAC
Impedance Meter	0.82	0.004	none	IML-1
Incubator (37 degrees centigrade)	50.00	0.160	0.400	WP-01
Incubators, Centrifugal (2)	80.00	0.320	0.600	BMAC
Ion Chromatograph	31.00	0.097	0.480	EHS
Isokinetic Dynamometer	84.82	0.479	1.100	ECF
Lab Sciences Workbench	350.00	0.960	0.800	WP-01
LBNP	20.00	0.150	0.060	BMAC
Life Sciences Glovebox	350.00	0.960	0.800	WP-01
Mass Measurement Device (Body)	34.50	0.651	0.020	SLS
Mass Measurement Device (Small)	17.00	0.080	0.015	WP-01
Mass Spectrometer (MGAS)	40.70	0.086	0.150	BMAC
Microscope System	100.00	0.400	0.400	WP-01
Mitogen Culture Device	2.00	0.007	0.150	BMAC
Model 12 Microlyzer	7.30	0.018	0.112	BMAC
Motion Analysis System	8.70	0.010	batteries	BMAC
Multichannel Data Recorder	20.00	0.073	0.060	BMAC
Osmometer	5.40	0.016	0.020	BMAC
Passive Dosimeter	35.00	0.085	none	WP-01
pH Meter/Ion Specific Analyzer	7.00	0.004	batteries	WP-01
Radiation Shielded Locker	80.00	0.200	0.000	WP-01
Radioimmunoassay	20.00	0.053	none	BMAC
Refrigerator (4 degrees centigrade)	40.00	0.150	0.450	WP-01
RIA Preparation Device	2.00	0.007	none	BMAC
Saliva Collection Device	0.17	0.001	none	BMAC
Sample Preparation Device (4 parts)	32.40	0.243	0.150	BMAC
Scintillation Counter	ground	ground	ground	BMAC
Slide Preparation Device	2.00	0.007	0.020	BMAC
Space Station Audio & Video Equipment	no cost to BMAC	no cost to BMAC	no cost to BMAC	S.S.F.
Specimen Labelling Device	4.00	0.010	0.020	WP-01
Spectrophotometer	40.00	0.110	0.300	WP-01
Subject Interface Box	4.33	0.018	none	IML-1
Telethermometer	15.00	0.019	0.014	BMAC
Tonometer	0.06	0.001	none	BMAC
Treadmill	82.55	0.450	0.500	ECF
Urine Monitoring/Analysis System	90.00	0.300	0.200	BMAC
Visual Function Testers (I,II,III)	6.80	0.120	batteries	AFMRL
Visual Tracking System	1.77	0.012	none	IML-1
Voice Recorder	0.20	0.001	none	SHUTTLE
Wrist Activity Monitor	0.10	0.001	batteries	IML-2
Totals	2703.71	10.500	11.448	

S.S. Freedom Mass, Volume, and Power charges to BMAC

2/14/90

Equipment Name	Mass (kilograms)	Volume (cubic meters)	Power (kilowatts)	Development Program	BMAC Funding Requirements
Blood Collection System	21.60	0.010	none	BMAC	total
Blood Flow and Plethysmography Syst	25.00	0.042	0.090	BMAC	total
Blood Pressure Instrumentation	15.50	0.022	0.200	BMAC	total
Carotid Sinus Baroreceptor Stimulato	45.30	0.124	0.225	BMAC	total
Cell Handling Accessories	1.00	0.010	none	BMAC	total
Cell Harvester	29.00	0.042	0.050	BMAC	total
Centrifuge, Hematocrit	0.83	0.001	batteries	BMAC	total
Centrifuge, Refrigerated	26.00	0.092	0.200	BMAC	total
Controlled Testing Units	109.80	0.525	0.000	BMAC	total
Crew Debrief/Analysis Software	none	none	none	BMAC	total
Electrocardiograph Recording Device	8.50	0.008	0.100	ECF	1 additional
Electroencephalogram	1.30	0.005	none	BMAC	total
Electromyograph Recording Device	2.00	0.007	0.020	BMAC	total
Electro-oculograph Recording Device	2.00	0.007	0.020	BMAC	total
ELISA Reader	6.00	0.200	0.100	BMAC	total
Experiment Control Computer System	67.00	0.278	0.250	BMAC	total
Experiment Control Data Interface	33.82	0.037	0.560	IML-1	modification
Fecal Monitoring System	25.00	0.118	0.050	BMAC	total
Flow Cytometer	36.00	0.235	0.500	BMAC	total
Fundus Camera	2.00	0.003	0.000	BMAC	total
Goniometer and Recorder	2.40	0.007	0.025	BMAC	total
Hard Tissue Imager	ground	ground	ground	BMAC	total
Heidelberg pH Capsule System	12.80	0.015	0.070	BMAC	total
Image Digitizing System	31.00	0.094	0.500	BMAC	total
Impedance Meter	0.82	0.004	none	IML-1	1 additional
Incubators, Centrifugal (2)	80.00	0.320	0.600	BMAC	modification
LBNP	20.00	0.150	0.060	BMAC	total
Mass Measurement Device (Body)	34.50	0.651	0.020	SLS	modification
Mass Spectrometer (MGAS)	40.70	0.086	0.150	BMAC	total
Mitogen Culture Device	2.00	0.007	0.150	BMAC	total
Model 12 Microlyzer	7.30	0.018	0.112	BMAC	total
Motion Analysis System	8.70	0.010	batteries	BMAC	total
Multichannel Data Recorder	20.00	0.073	0.060	BMAC	total
Osmometer	5.40	0.016	0.020	BMAC	total
Radioimmunoassay	20.00	0.053	none	BMAC	total
RIA Preparation Device	2.00	0.007	none	BMAC	total
Saliva Collection Device	0.17	0.001	none	BMAC	total
Sample Preparation Device	32.40	0.243	0.150	BMAC	total
Scintillation Counter	ground	ground	ground	BMAC	total
Slide Preparation Device	2.00	0.007	0.020	BMAC	total
Subject Interface Box	4.33	0.018	none	IML-1	modification
Telethermometer	15.00	0.019	0.014	BMAC	total
Tonometer	0.06	0.001	none	BMAC	total
Urine Monitoring/Analysis System	90.00	0.300	0.200	BMAC	total
Visual Function Testers (I,II,III)	6.80	0.120	batteries	AFMRL	none
Visual Tracking System	1.77	0.012	none	IML-1	modification
Voice Recorder	0.20	0.001	none	SHUTTLE	1 additional
Wrist Activity Monitor	0.10	0.001	batteries	IML-2	1 additional
Totals	898.10	4.000	4.516		

WP-01/S.S. Freedom Baseline Provided Items

Equipment Name	Mass (kilograms)	Volume (cubic meters)	Power (kilowatts)	Development Program
Echocardiograph/Doppler Velocimeter	70.00	0.200	0.600	WP-01
Fluid Handling Tools/System	80.00	0.480	0.100	WP-01
Freeze Dryer	19.00	0.067	0.140	WP-01
Freezer (-20 degrees centigrade)	120.00	0.480	0.300	WP-01
Freezer (-70 degrees centigrade)	120.00	0.480	0.300	WP-01
HPLC	40.00	0.120	0.100	WP-01
Incubator (37 degrees centigrade)	50.00	0.160	0.400	WP-01
Lab Sciences Workbench	350.00	0.960	0.800	WP-01
Life Sciences Glovebox	350.00	0.960	0.800	WP-01
Mass Measurement Device (Small)	17.00	0.080	0.015	WP-01
Microscope System	100.00	0.400	0.400	WP-01
Passive Dosimeter	35.00	0.085	none	WP-01
pH Meter/Ion Specific Analyzer	7.00	0.004	batteries	WP-01
Radiation Shielded Locker	80.00	0.200	0.000	WP-01
Refrigerator (4 degrees centigrade)	40.00	0.150	0.450	WP-01
Space Station Audio & Video Equipment	no cost to BMAC	no cost to BMAC	no cost to BMAC	S.S.F.
Specimen Labelling Device	4.00	0.010	0.020	WP-01
Spectrophotometer	40.00	0.110	0.300	WP-01
Totals	1522.00	4.946	4.725	

CHeCS Provided Items

Equipment Name	Mass (kilograms)	Volume (cubic meters)	Power (kilowatts)	Development Program
Bioimpedance Analyzer	4.54	0.005	0.002	ECF
Chemistry System	23.00	0.093	0.100	HMF
Drug Administration Equipment	1.00	0.005	none	HMF
Ergometer (Bicycle/Rower)	56.70	0.425	0.025	ECF
Ion Chromatograph	31.00	0.097	0.480	EHS
Isokinetic Dynamometer	84.82	0.479	1.100	ECF
Treadmill	82.55	0.450	0.500	ECF
Totals	283.61	1.554	2.207	

2/9/90

Shuttle/Spacelab Provided Items

Equipment Name	Mass (kilograms)	Volume (cubic meters)	Power (kilowatts)	Development Program
Equi-Test Posture Platform	ground	ground	ground	EDO
Equi-Test Instrumentation Racks	ground	ground	ground	EDO
Totals	0.00	0.000	0.000	

Equipment Name	Development Program	Funding	Estimated Cost (K's)
Bioimpedance Analyzer	ECF	none	0
Blood Collection System	BMAC	total	640
Blood Flow and Plethysmography System	BMAC	total	1389
Blood Pressure Instrumentation	BMAC	total	1497
Carotid Sinus Baroreceptor Stimulator	BMAC	total	877
Cell Handling Accessories	BMAC	total	66
Cell Harvester	BMAC	total	6437
Centrifuge, Hematocrit	BMAC	total	45
Centrifuge, Refrigerated	BMAC	total	4417
Chemistry System	HMF	modification	528
Controlled Testing Units	BMAC	total	257
Crew Debrief/Analysis Software	BMAC	total	194
Drug Administration Equipment	HMF	none	0
Echocardiograph/Doppler Velocimeter	WP-01	none	0
Electrocardiograph Recording Device	ECF	modification	50
Electroencephalogram	BMAC	total	521
Electromyograph Recording Device	BMAC	total	488
Electro-oculograph Recording Device	BMAC	total	669
ELISA Reader	BMAC	total	3587
Equi-Test Posture Platform	EDO	modification	120
Equi-Test Instrumentation Racks	EDO	modification	30
Ergometer (Bicycle/Rower)	ECF	none	0
Experiment Control Computer System	BMAC	total	4005
Experiment Control Data Interface	IML-1	modification	107
Fecal Monitoring System	BMAC	total	4551
Flow Cytometer	BMAC	total	4102
Fluid Handling Tools/System	WP-01	none	0
Freeze Dryer	WP-01	none	0
Freezer (-20 degrees centigrade)	WP-01	none	0
Freezer (-70 degrees centigrade)	WP-01	none	0
Fundus Camera	BMAC	total	120
Goniometer and Recorder	BMAC	total	52
Hard Tissue Imager	BMAC	ground	0
Heidelberg pH Capsule System	BMAC	total	75
HPLC	WP-01	none	0
Image Digitizing System	BMAC	total	4263
Impedance Meter	IML-1	1 additional	15
Incubator (37 degrees centigrade)	WP-01	none	0
Incubators, Centrifugal (2)	BMAC	modification	3515
Ion Chromatograph	EHS	none	0
Isokinetic Dynamometer	ECF	none	0
Lab Sciences Workbench	WP-01	none	0
LBNP	BMAC	total	1212
Life Sciences Glovebox	WP-01	none	0
Mass Measurement Device (Body)	SLS	modification	750
Mass Measurement Device (Small)	WP-01	none	0
Mass Spectrometer (MGAS)	BMAC	total	4963
Microscope System	WP-01	none	0
Mitogen Culture Device	BMAC	total	2743
Model 12 Microlyzer	BMAC	total	250
Motion Analysis System	BMAC	total	337
Multichannel Data Recorder	BMAC	total	2596
Osmometer	BMAC	total	150
Passive Dosimeter	WP-01	none	0
pH Meter/Ion Specific Analyzer	WP-01	none	0
Radiation Shielded Locker	WP-01	none	0
Radioimmunoassay	BMAC	total	1100
Refrigerator (4 degrees centigrade)	WP-01	none	0
RIA Preparation Device	BMAC	total	101
Saliva Collection Device	BMAC	total	15
Sample Preparation Device (4 parts)	BMAC	total	12599
Scintillation Counter	BMAC	ground	0
Slide Preparation Device	BMAC	total	3100
Space Station Audio & Video Equipment	S.S.F.	none	0
Specimen Labelling Device	WP-01	none	0
Spectrophotometer	WP-01	none	0
Subject Interface Box	IML-1	modification	30
Telethermometer	BMAC	total	798
Tonometer	BMAC	total	81
Treadmill	ECF	none	0
Urine Monitoring/Analysis System	BMAC	total	5910
Visual Function Testers (I,II,III)	AFMRL	none	0
Visual Tracking System	IML-1	modification	20
Voice Recorder	SHUTTLE	1 additional	6
Wrist Activity Monitor	IML-2	1 additional	12
Totals			79390

Mass, Power, Volume, Devolpment and Funding for BMAC used Equipment 2/14/90

Equipment Name	Mass (kilograms)	Volume (cubic meters)	Power (kilowatts)	Development Program	BMAC Funding Requirements
Bioimpedance Analyzer	4.54	0.005	0.002	ECF	none
Blood Collection System	21.60	0.010	none	BMAC	total
Blood Flow and Plethysmography Syst	25.00	0.042	0.090	BMAC	total
Blood Pressure Instrumentation	15.50	0.022	0.200	BMAC	total
Carotid Sinus Baroreceptor Stimulato	45.30	0.124	0.225	BMAC	total
Cell Handling Accessories	1.00	0.010	none	BMAC	total
Cell Harvester	29.00	0.042	0.050	BMAC	total
Centrifuge, Hematocrit	0.83	0.001	batteries	BMAC	total
Centrifuge, Refrigerated	26.00	0.092	0.200	BMAC	total
Chemistry System	23.00	0.093	0.100	HMF	modification
Controlled Testing Units	109.80	0.525	0.000	BMAC	total
Crew Debrief/Analysis Software	none	none	none	BMAC	total
Drug Administration Equipment	1.00	0.005	none	HMF	none
Echocardiograph/Doppler Velocimeter	70.00	0.200	0.600	WP-01	none
Electrocardiograph Recording Device	8.50	0.008	0.100	ECF	modification
Electroencephalogram	1.30	0.005	none	BMAC	total
Electromyograph Recording Device	2.00	0.007	0.020	BMAC	total
Electro-oculograph Recording Device	2.00	0.007	0.020	BMAC	total
ELISA Reader	6.00	0.200	0.100	BMAC	total
Equi-Test Posture Platform	ground	ground	ground	EDO	ground
Equi-Test Instrumentation Racks	ground	ground	ground	EDO	ground
Ergometer (Bicycle/Rower)	56.70	0.425	0.025	ECF	none
Experiment Control Computer System	67.00	0.278	0.250	BMAC	total
Experiment Control Data Interface	33.82	0.037	0.560	IML-1	modification
Fecal Monitoring System	25.00	0.118	0.050	BMAC	total
Flow Cytometer	36.00	0.235	0.500	BMAC	total
Fluid Handling Tools/System	80.00	0.480	0.100	WP-01	none
Freeze Dryer	19.00	0.067	0.140	WP-01	none
Freezer (-20 degrees centigrade)	120.00	0.480	0.300	WP-01	none
Freezer (-70 degrees centigrade)	120.00	0.480	0.300	WP-01	none
Fundus Camera	2.00	0.003	0.000	BMAC	total
Goniometer and Recorder	2.40	0.007	0.025	BMAC	total
Hard Tissue Imager	ground	ground	ground	BMAC	ground
Heidelberg pH Capsule System	12.80	0.015	0.070	BMAC	total
HPLC	40.00	0.120	0.100	WP-01	none
Image Digitizing System	31.00	0.094	0.500	BMAC	total
Impedance Meter	0.82	0.004	none	IML-1	1 additional
Incubator (37 degrees centigrade)	50.00	0.160	0.400	WP-01	none
Incubators, Centrifugal (2)	80.00	0.320	0.600	BMAC	modification
Ion Chromatograph	31.00	0.097	0.480	EHS	none
Isokinetic Dynamometer	84.82	0.479	1.100	ECF	none
Lab Sciences Workbench	350.00	0.960	0.800	WP-01	none
LBNP	20.00	0.150	0.060	BMAC	total
Life Sciences Glovebox	350.00	0.960	0.800	WP-01	none
Mass Measurement Device (Body)	34.50	0.651	0.020	SLS	modification
Mass Measurement Device (Small)	17.00	0.080	0.015	WP-01	none
Mass Spectrometer (MGAS)	40.70	0.086	0.150	BMAC	total
Microscope System	100.00	0.400	0.400	WP-01	none
Mitogen Culture Device	2.00	0.007	0.150	BMAC	total
Model 12 Microlyzer	7.30	0.018	0.112	BMAC	total
Motion Analysis System	8.70	0.010	batteries	BMAC	total
Multichannel Data Recorder	20.00	0.073	0.060	BMAC	total
Osmometer	5.40	0.016	0.020	BMAC	total
Passive Dosimeter	35.00	0.085	none	WP-01	none
pH Meter/Ion Specific Analyzer	7.00	0.004	batteries	WP-01	none
Radiation Shielded Locker	80.00	0.200	0.000	WP-01	none
Radioimmunoassay	20.00	0.053	none	BMAC	total
Refrigerator (4 degrees centigrade)	40.00	0.150	0.450	WP-01	none
RIA Preparation Device	2.00	0.007	none	BMAC	total
Saliva Collection Device	0.17	0.001	none	BMAC	total
Sample Preparation Device	32.40	0.243	0.150	BMAC	total
Scintillation Counter	ground	ground	ground	BMAC	ground
Slide Preparation Device	2.00	0.007	0.020	BMAC	total
Space Station Audio & Video Equipme	no cost to BMAC	no cost to BMAC	no cost to BMAC	S.S.F.	none
Specimen Labelling Device	4.00	0.010	0.020	WP-01	none
Spectrophotometer	40.00	0.110	0.300	WP-01	none
Subject Interface Box	4.33	0.018	none	IML-1	modification
Telethermometer	15.00	0.019	0.014	BMAC	total
Tonometer	0.06	0.001	none	BMAC	total
Treadmill	82.55	0.450	0.500	ECF	none
Urine Monitoring/Analysis System	90.00	0.300	0.200	BMAC	total
Visual Function Testers (I,II,III)	6.80	0.120	batteries	AFMRL	none
Visual Tracking System	1.77	0.012	none	IML-1	modification
Voice Recorder	0.20	0.001	none	SHUTTLE	1 additional
Wrist Activity Monitor	0.10	0.001	batteries	IML-2	1 additional
Totals	2703.71	10.500	11.448		

THE SPACE STATION FREEDOM

BIOMEDICAL MONITORING AND COUNTERMEASURES (BMAC)

PROJECT

Preface

The requirement to certify astronauts for continuous work on Space Station Freedom has resulted in the identification of the Biomedical Monitoring and Countermeasures Program. As a result of this program, 19 operationally important problems have been identified, researched and documented. Five maintenance goals, which includes the ability to perform work, normal bodily functions, mental and social well-being, normal bodily state, and normal risk levels have been utilized in grouping the operationally important problems.

This document contains the 19 operationally important problems grouped into the five maintenance goals. Two formats for each problems is included; 1) the prose detailing the historical background, recommendations for monitoring, anticipated countermeasures and bibliography 2) a vu-graph presentation of the above.

OPERATIONALLY IMPORTANT FACTORS AFFECTING HEALTH AND PERFORMANCE DURING LONG - DURATION SSF OCCUPATION

MAINTENANCE GOAL	OPERATIONALLY IMPORTANT PROBLEMS
ABILITY TO PERFORM WORK	1. INCREASED MUSCULAR FATIGUE / DECREASED MUSCULAR STRENGTH 2. DECREASED ABILITY TO PERFORM LONG DURATION TASKS 3. DECREASED ABILITY TO PERFORM HIGH PRECISION TASKS 4. DECREASED ABILITY TO EMERGENCY EGRESS
NORMAL BODILY FUNCTIONS	5. SLEEP DISORDERS 6. VISUAL DYSFUNCTION 7. IMPAIRED THERMOREGULATION

BIOMEDICAL MONITORING AND COUNTERMEASURES PROGRAM

SPACE STATION FREEDOM

GERALD TAYLOR, Ph.D | DECEMBER 21, 1989

OPERATIONALLY IMPORTANT FACTORS AFFECTING HEALTH AND PERFORMANCE DURING LONG - DURATION SSF OCCUPATION

MAINTENANCE GOAL	OPERATIONALLY IMPORTANT PROBLEMS
MENTAL AND SOCIAL WELL-BEING	8. CHANGE IN MOOD / MOTIVATION 9. IMPAIRED COGNITION 10. INTERPERSONAL CONFLICT 11. PSYCHOPHYSIOLOGICAL STRESS
NORMAL BODILY STATE	12. ANEMIA 13. INFECTION 14. ALTERED PHARMACOLOGIC ACTIVITY 15. ALTERED CARDIOVASCULAR FUNCTION
NORMAL RISK LEVELS	16. RENAL STONES 17. CARDIAC DYSRHYTHMIAS 18. CANCER INDUCTION 19. OSTEOPOROSIS AND FRACTURES

ABILITY TO PERFORM WORK

INCREASED MUSCULAR FATIGUE / DECREASED MUSCULAR STRENGTH

Historical Background

Early observations in humans of significant decreases in muscle tone, muscle strength, muscular endurance, and physical work capacity were noted during the inflight and immediate postflight periods of a mission (Pestov, 1975, pp. 305-354; Thornton, 1977, pp. 191-197; Whedon, et al., 1977, pp. 164-174). Decrements in the strength of the arm and leg muscles of the Skylab astronauts were noted, with the decrement in arm extensors and flexors less than those of the legs (Thornton, 1977; pp. 191-197; Nicogossian, et al., 1989). The leg strength loss averaged 20-25% from preflight values; in the arms, the average loss was only 4% (range 10% loss to 5% gain). These changes were felt to be related to the exercise modalities used during Skylab, but the extent of this relationship is unknown. Observations of minimal to moderate losses of nitrogen and postflight weight loss were consistent with muscle atrophy which would then lead to decreased muscular strength and increased muscular fatigue (Dietlein, 1977, pp. 408-418).

Loss of muscular strength and muscle atrophy was noted in the Robbins committee report as an identifiable change that occurs with extended duration space flight (Robbins Report, 1988, pp. 18, 45, 49). The impact of muscle loss on performance of astronauts during space flight was deemed as unclear by the committee, as inflight activities (exclusive of EVA) require a minimal amount of muscular strength (Robbins Report, 1988, p. 46). Muscle atrophy and strength loss due to long term space flight was noted in A Strategy for Space Biology and Medical Science. (Goldberg Report, 1987, p. 146). EMG data collected during Skylab has indicated reduced muscular efficiency and increased susceptibility to fatigue. The committee suggested that the operational significance of these losses were uncertain as: "Methods used to evaluate muscle physiology have been rudimentary and have only been employed postflight . There have been no measures in space of typical muscle forces that occur...because of these limitations, we do not know the end point of space disuse atrophy or the time course with which it is reached." (Goldberg Report, 1987, pp. 146, 147). The committee speculated that missions lasting from several weeks to months will not likely lead to serious clinical inflight or postflight difficulties; however, concerns regarding rapid egress were apparently not considered.

The life sciences research office of the Federation of American Societies for Experimental Biology published a committee report regarding research opportunities in muscle atrophy caused by space flight (FASEB - Muscle Atrophy, 1984). In the report it was noted that loss of skeletal muscle resulting from atrophy has, apparently, not compromised crew functions "...except, possibly during extravehicular activity and lunar surface EVA in Apollo 15... during the lunar surface activities two of the Apollo 15 crew developed cardiac arrhythmias" (FASEB - Muscle Atrophy, 1984, p. 21). The Federation committee noted that other changes caused by microgravity-induced muscular atrophy include a reduction of muscle volume, mass, exercise (aerobic) capacity, and neuromuscular coordination (FASEB - Muscle Atrophy, 1984, pp. 16-19).

Recommendations for Monitoring

Appropriate monitoring for both muscular strength and fatigue changes pre- to postflight and inflight can be accomplished with the use of an isokinetic dynamometer. These tests could be accomplished on a weekly basis. The dynamometer should be capable of measuring both concentric (shortening) and eccentric (lengthening) muscle forces. A device capable of measuring only concentric forces was used to quantify strength changes pre- to postflight during the Skylab series of flights (Thornton and Rummel, 1977, pp, 191-197). These measures should be taken at the hand, wrist, elbow, shoulder, trunk, knee, and ankle. A crude way to study the changes in lean body mass that precipitate changes in strength would be measures of body mass and body composition. Electromyographic (EMG) data would provide information on changes in muscle recruitment patterns.

Anticipated Countermeasures

Appropriately prescribed exercise, assurance that the RDA for protein is maintained in diet.

Related Operationally Important Problems

Decreased Ability To Emergency Egress
Cardiac Dysrhythmias

Dietlein L. "Skylab: A beginning." Johnston R, Dietlein L, editors. *Biomedical Results from Skylab*. Washington, D.C.: NASA; 1977:408-418.

FASEB. Talbot J, Fisher K, editors. *Research Opportunities In Muscle Atrophy*. Bethesda: Federation of American Societies for Experimental Biology; NASW 3924, 198[illegible].

Goldberg J, et al. *A Strategy for Space Biology*. Washington, D.C.: National Academic Press; 1987.

Nicogossian A. "Countermeasures to space deconditioning." Nicogossian A, Huntoon C, Pool S, editors. *Space Physiology and Medicine*. Philadelphia: Lea and Febiger; 1989:294-311.

Pestov I and Geratewohl S. "Weightlessness." Calvin M, Gazenko O, editors. *Foundations of Space Biology and Medicine*. Washington, D.C.: NASA; 1975:305-354.

Robbins F, et al. *Exploring the Living Universe/A Strategy for Space Life Sciences*. Washington, D.C.: NASA; 1988.

Thornton W and Rummel J. "Muscular deconditioning and its prevention in space flight." Johnston R, Dietlein L, editors. *Biomedical Results from Skylab*. Washington, D.C.: NASA; 1977:191-197.

Whedon G, Lutwak L, Raumbaut P, Whittle M, Smith M, Ried J, Leach C, Stadler C and Sanford D. "Mineral and nitrogen metabolic studies, experiment MO71." Johnston R, Dietlein L, editors. *Biomedical Results from Skylab*. Washington, D.C.: NASA; 1977:164-174.

HISTORICAL BACKGROUND

- SIGNIFICANT DECREASES IN MUSCLE TONE, MUSCLE STRENGTH, MUSCULAR ENDURANCE AND PHYSICAL WORK CAPACITY HAVE BEEN NOTED
- LEG STRENGTH LOSS AVERAGED 20 - 25% FROM PREFLIGHT VALUES FOR SKYLAB ASTRONAUTS

SIGNIFICANCE

- LOSS OF STRENGTH AND AN INCREASE IN FATIGUE MAY ADVERSELY IMPACT THE ABILITY TO PERFORM EMERGENCY EGRESS, AND THE ABILITY TO COMPLETE STRENUOUS EVA OR IVA TASKS

RECOMMENDATIONS FOR MONITORING

- **MONITOR**
  - ECCENTRIC AND CONCENTRIC MUSCLE STRENGTH AT MAJOR JOINTS
  - ECCENTRIC AND CONCENTRIC MUSCLE FATIGUE AT MAJOR JOINTS
  - EMG DURING MUSCLE FUNCTION TESTING
  - BODY MASS

INCREASED MUSCULAR FATIGUE / DECREASED MUSCULAR STRENGTH

Presenter: GERALD TAYLOR / JSC

Date: DEC. 21, 1989

- HYPOTHESIZED RESULTS AND SIGNIFICANCE
  - DECREASED MUSCLE STRENGTH AND INCREASED MUSCULAR FATIGUE, THE MAGNITUDE OF WHICH WILL BE HIGHER IN THE LEGS, IS EXPECTED

ANTICIPATED COUNTERMEASURES

- APPROPRIATELY PRESCRIBED EXERCISE
- ASSURANCE THAT PROTEIN REQUIREMENTS ARE MAINTAINED IN DIET

INCREASED MUSCULAR FATIGUE / DECREASED MUSCULAR STRENGTH

Presenter:
GERALD TAYLOR / JSC

Date:
DEC. 21, 1989

RELATED OPERATIONALLY IMPORTANT PROBLEMS

- DECREASED ABILITY TO EMERGENCY EGRESS
- DECREASED ABILITY TO PERFORM LONG DURATION TASKS
- DECREASED ABILITY TO PERFORM HIGH PRECISION TASKS

DECREASED ABILITY TO PERFORM LONG DURATION TASKS

Historical Background

The ability to perform long duration tasks is dependent, primarily, on the aerobic capacity of an individual. Aerobic capacity can be altered by factors that act in the cardiovascular system (central changes), and by changes that occur in the skeletal muscles (peripheral changes). Studies of aerobic capacity, measured during leg exercise (bicycle ergometer) during the 84 d mission of Skylab, indicated that aerobic capacity was not compromised in those individuals (Michel, et al., 1977, pp. 191-197; Thornton and Rummel, 1977, pp. 191-197). This finding was felt to be influenced by the use of a cycle ergometer for daily exercise by the crew. To date, there have been no studies of aerobic capacity changes during arm ergometry, on long duration flights.

Estimates of the oxygen cost during EVA activities have been performed during Apollo, Skylab, and Shuttle missions (Convertino, 1990, Waligora, et al., 1975, pp. 115-128; Waligora, et al., 1977, pp. 395-399). The mean oxygen uptake estimates during EVA have remained similar for the three programs at 0.9 liters/min. The peak oxygen uptake required for tasks lasting several minutes was 1.6 liters/min. To put these numbers into perspective, the average maximum oxygen uptake of males sharing similar physical characteristics of the astronauts is 2.7 liters/min. The maximum oxygen consumption expected to be elicited by arm work alone is approximately 70 % of this value. or 1.9 liters/min (ACSM, 1986). Therefore, males performing EVA are routinely working at approximately 45-50% of their maximum upper body oxygen consumption capacity, and levels of up to 85% of their maximum capacity are required. A workload of >70-80% will induce metabolic acidosis in most individuals. Thus, a loss of the aerobic capacity of the arms could seriously impact the ability to perform EVA.

Muscle atrophy was noted in the Robbins committee report as an identifiable change that occurs with extended duration space flight (Robbins Report, 1988, pp. 18, 45, 49). The impact of muscle loss on performance of astronauts during space flight was deemed as unclear by the committee, since inflight activities (exclusive of EVA) require a minimal amount of muscular strength (Robbins Report, 1988, p. 46). Muscle atrophy, due to long term space flight, was noted in A Strategy for Space Biology and Medical Science. (Goldberg Report, 1987, p. 146). The committee suggested that the operational significance of this loss is uncertain as: "Methods used to evaluate muscle physiology have been rudimentary and have only been employed postflight . There have been no measures in space of typical muscle forces that occur...because of these limitations, we do not know the end point of space disuse atrophy or the time course with which it is reached." (Goldberg Report, 1987, pp. 146, 147). The committee does suggest that missions lasting from several weeks to months will not likely lead to serious clinical inflight or postflight difficulties; however, it is unclear whether the committee considered unscheduled EVA activities or emergency egress.

The life sciences research office of the Federation of American Societies for Experimental Biology published a committee report regarding research opportunities in muscle atrophy caused by space flight (FASEB - Muscle Atrophy, 1984). In this report, it was noted that loss of skeletal muscle resulting from atrophy has, apparently, not compromised crew functions "...except, possibly during extravehicular activity and lunar surface EVA in Apollo 15... during the lunar surface activities two of the Apollo 15 crew developed cardiac arrhythmias." (FASEB, 1984, p. 21). The Federation committee noted that changes caused by microgravity-induced muscular atrophy include a reduction of muscle volume, mass, exercise (aerobic) capacity, and neuromuscular coordination (FASEB - Muscle Atrophy, 1984, pp. 16-19).

Recommendations for Monitoring

Appropriate monitoring for measuring the aerobic capacity of the arms is to measure the maximum oxygen consumption response to a graded exercise arm task. These tests could be conducted bi-weekly. The testing modality would be a type of arm ergometer. A metabolic measurement unit would be required to measure oxygen consumption. Although not critical to measurement of aerobic capacity, a means of monitoring the ECG response to the work is recommended for safety considerations.

Anticipated Countermeasures

Appropriately prescribed exercise, assurance that the RDA for protein is maintained in diet.

Related Operationally Important Problems

Impaired Thermoregulation
Decreased Muscular Fatigue / Increased Muscular Strength

American College of Sports Medicine. *Guidelines for Exercise Testing and Prescription.* Philadelphia: Lea and Febiger; 1986.

Coventino V. "Physiological Adaptations to Weightlessness: Effects on Exercise and Work Performance. *Exer Sports Science Rev.* 1990; 18:in press.

Dietlein L. "Skylab: A beginning." Johnston R, Dietlein L, editors. *Biomedical Results from Skylab.* Washington, D.C.: NASA; 1977:408-418.

FASEB. Talbot J, Fisher K, editors. *Research Opportunities in Muscle Atrophy.* Bethesda: Federation of American Societies for Experimental Biology; NASW 3924, 1985.

Goldberg J, et al. *A Strategy for Space Biology.* Washington, D.C.: National Academic Press; 1987.

Michel E, Rummel J and Sawin C. "Results of skylab medical experiment M171 - metabolic activity." Johnston R, Dietlein L, editors. *Biomedical Results from Skylab.* Washington, D.C.: NASA; 1977:191-197.

Pestov I and Geratewohl S. "Weightlessness." Calvin M, Gazenko O, editors. *Foundations of Space Biology and Medicine.* Washington, D.C.: NASA; 1975:305-354.

Robbins F, et al. *Exploring the Living Universe/A Strategy for Space Life Sciences.* Washington, D.C.: NASA; 1988.

Thornton W and Rummel J. "Muscle deconditioning and its prevention in space flight." Johnston R, Dietlein L, editors. *Biomedical Results from Skylab.* Washington, D.C.: NASA; 1977:191-197.

Waligora J and Horrigan D. "Metabolism and heat dissipation during Apollo EVA periods." Johnston R, Dietlein L, Berry C, editors. *Biomedical Results of Apollo.* Washington, D.C.: NASA; 1975:115-128.

Waligora J and Horrigan D. "Metabolic cost of extravehicular activities." Johnston R, Dietlein L, editors. *Biomedical Results From Skylab.* Washington, D.C.: NASA; 1977:395-399.

Whedon G, Lutwak L, Raumbaut P, Whittle M, Smith M, Ried J, Leach C, Stadler C and Sanford D. "Mineral and nitrogen metabolic studies, experiment M071." Johnston R, Dietlein L, editors. *Biomedical Results from Skylab.* Washington, D.C.: NASA; 1977:164-174.

DECREASED ABILITY
TO PERFORM
LONG DURATION TASKS

BIOMEDICAL MONITORING
AND
COUNTERMEASURES

Presenter: GERALD TAYLOR / JSC

Date: DEC. 21, 1989

HISTORICAL BACKGROUND

- SIGNIFICANT DECREASES IN MUSCLE TONE, MUSCLE STRENGTH, MUSCULAR ENDURANCE AND PHYSICAL WORK CAPACITY HAVE BEEN NOTED
- AEROBIC CAPACITY MEASURED DURING LEG CYCLE ERGOMETRY (84 D SKYLAB MISSION) WAS NOT COMPROMISED
- NO INFLIGHT STUDIES HAVE BEEN CONDUCTED REGARDING ARM EXERCISE AND AEROBIC CAPACITY CHANGES
- MALES PERFORMING EVA ARE ROUTINELY WORKING AT 45-50% OF THEIR PREFLIGHT UPPER BODY AEROBIC CAPACITY, AND LEVELS OF UP TO 85% OF THEIR MAXIMUM AEROBIC UPPER BODY CAPACITY ARE ATTAINED

C-2

DECREASED ABILITY TO PERFORM LONG DURATION TASKS

SIGNIFICANCE

- LOSS OF AEROBIC CAPACITY, PARTICULARLY IF UPPER BODY AEROBIC CAPACITY IS DECREASED, WILL INHIBIT THE ABILITY TO COMPLETE STRENUOUS EVA AND IVA TASKS

RECOMMENDATIONS FOR MONITORING

- MONITOR
  - OXYGEN CONSUMPTION DURING MAXIMAL UPPER BODY GRADED EXERCISE TESTING
  - ECG RESPONSE TO UPPER BODY GRADED EXERCISE TESTS

DECREASED ABILITY TO PERFORM LONG DURATION TASKS

• HYPOTHESIZED RESULTS AND SIGNIFICANCE

- DECREASED AEROBIC CAPACITY OF THE ARMS IS EXPECTED. THIS DECREASE WILL NOT LIKELY AFFECT MOST OPERATIONS, BUT WILL DECREASE THE ABILITY OF THE ASTRONAUTS TO COMPLETE STRENUOUS EVA AND IVA TASKS

ANTICIPATED COUNTERMEASURES

- APPROPRIATELY PRESCRIBED EXERCISE
- ASSURANCE THAT PROTEIN REQUIREMENTS ARE MAINTAINED IN THE DIET

RELATED OPERATIONALLY IMPORTANT PROBLEMS

- DECREASED ABILITY TO EMERGENCY EGRESS

DECREASED ABILITY TO PERFORM HIGH PRECISION TASKS

Historical Background

Vestibular disturbances during the initial adaptation to microgravity are well documented, the most well-known of these being space motion sickness. Accompanying space motion sickness are reports of visual, orientational, proprioceptive, and self-motion illusions. In most cases the time course of adaptation for vestibular dysfunctions is 2 to 4 days with no recurrence of symptoms after this period (Homick and Vanderploeg, 1989, p. 156).

The most widely accepted theory used to explain the changes that take place in microgravity is the theory of sensory rearrangement. In a normal 1-G environment, human spatial orientation is determined by four sensory inputs. "These are (1) otolith information on gravity vector and linear accelerations, (2) angular acceleration data provided by the semicircular canals, (3) visual information concerning body orientation, and (4) touch pressure and kinesthetic information" (Nicogossian, 1982, p. 146). With the transition to microgravity, these inputs must be "rearranged" to optimize the response to a different gravity environment.

While this is desirable for the performance of high precision tasks in a microgravity environment, the ensuing re-adaptation that occurs during reentry and landing is associated with a reappearance of vestibular side effects; changes in neurosensory and sensorimotor control programs which were appropriate for microgravity, are now inappropriate for a 1-G environment. The ability to perform high precision tasks may be severely compromised especially if visual cues are reduced (as in an emergency situation) (Parker, et al., 1989, p. 170). Therefore, it is necessary to determine how and to what extent visual and manual control tasks are affected as a function of mission duration.

Numerous inflight performance studies by both U.S. and Soviet investigators, support the view that there is no impairment of sensorimotor performance inflight after the initial adaptation period has taken place (Parker, et al., 1989, p. 177). Complex sensorimotor tasks can be performed with precision and accuracy assuming that the operator is in optimum condition and the man/machine interface is well designed (Nicogossian, 1982, p. 163). Questions do remain; however, concerning decrements in performance following prolonged missions (Parker, et al., 1989, p. 167).

The Robbins committee report recommends correlating changes in task performance with vestibular and otolith function inflight and states that "other possible effects of space flight on neurosensory and biobehavioral function are unknown and should be explored if we intend to achieve a permanent human presence in space" (Robbins Report, 1988, p. 49). The Goldberg committee report describes goals and objectives for areas relevant to sensorimotor adaptation such as spatial orientation, postural mechanisms, the vestibulo-ocular reflex, and processing in the vestibular system. (Goldberg Report, 1987, p. 6)

Recommendations for Monitoring

Appropriate monitoring activities would include: visual pursuit tracking/target acquisition; subjective reporting of illusory phenomena; verification of the otolith-reinterpretation hypothesis; correlation of task performance with changes in vestibular and otolith function; and evaluation of limb position sense, muscle tone and reflexive loop gain.

Related Operationally Important Problems

Decreased Ability to Respond to Inflight Emergency
Decreased Ability to Emergency Egress
Visual Dysfunction
Impaired Cognition

Goldberg J, et al. *A Strategy for Space Biology*. Washington, D.C.: National Academic Press; 1987.

Homick J and Vanderploeg J. "The neurovestibular system." Nicogossian A, Huntoon C, Pool S, editors. *Space Physiology and Medicine*. Philadelphia: Lea and Febiger; 1989:154-164.

Nicogossian A and Parker J, et al. *Space Physiology and Medicine*. Washington D.C.: NASA; 1982.

Parker D, Reschke M and Aldrich N. "Performance." Nicogossian A, Huntoon C, Pool S, editors. *Space Physiology and Medicine*. Philadelphia: Lea and Febiger; 1989:167-178.

Robbins F, et al. *Exploring The Living Universe: A Strategy for Space Life Sciences*. Washington, D.C.: NASA; 1988.

HISTORICAL BACKGROUND

- ANECDOTAL REPORTS FROM CREWMEMBERS DESCRIBE ILLUSIONS OF SELF-MOTION AND MOTION OF THE VISUAL SURROUNDINGS ELICITED BY HEAD MOVEMENTS DURING TRANSITION BETWEEN G ENVIRONMENTS

- RESULTS OF U.S. AND SOVIET INVESTIGATIONS, BOTH SHORT AND LONG DURATION, INDICATE THAT TASK PERFORMANCE IS NOT COMPROMISED ONCE THE INITIAL ADAPTATION HAS OCCURRED

- HOWEVER, READAPTATION TO A 1-G ENVIRONMENT IS CHARACTERIZED BY A REAPPEARANCE OF VESTIBULAR SIDE EFFECTS WHICH CAN COMPROMISE NEUROMUSCULAR PERFORMANCE

DECREASED ABILITY TO PERFORM HIGH PRECISION TASKS

SIGNIFICANCE

- ABILITY TO PERFORM HIGH PRECISION TASKS COULD BE SIGNIFICANTLY COMPROMISED DURING PERIODS OF ADAPTATION TO MICROGRAVITY AND READAPTATION TO ONE - G, AND IS PROPORTIONAL TO MISSION DURATION

RECOMMENDATIONS FOR MONITORING

- MONITOR
  - VISUAL PURSUIT TRACKING / TARGET ACQUISITION
  - SPATIAL DISORIENTATION INDUCED BY HEAD MOVEMENTS
  - CHANGES IN LIMB POSITION SENSE, MUSCLE TONE, AND REFLEXIVE LOOP GAIN

- **HYPOTHESIZED RESULTS AND SIGNIFICANCE**

  - MODIFICATION OF NEUROMUSCULAR, VISUAL - VESTIBULAR, SOMATOSENSORY AND CUTANEOUS COMPONENTS COMPRISING SENSORY INPUT

  - SENSORY REARRANGEMENT WILL IMPACT HIGH PRECISION TASKS PERFORMED DURING THE TRANSITION BETWEEN G ENVIRONMENTS; THE DEGREE OF IMPACT WILL BE PROPORTIONAL TO THE DURATION OF THE MISSION

DECREASED ABILITY
TO PERFORM
HIGH PRECISION TASKS

BIOMEDICAL MONITORING AND COUNTERMEASURES	
Presenter: GERALD TAYLOR / JSC	Date: DEC. 21, 1989

ANTICIPATED COUNTERMEASURES

- MODIFICATION OF CREW PROCEDURES / EQUIPMENT TO MINIMIZE IMPACT OF SENSORIMOTOR REARRANGEMENT DURING TRANSITION PERIODS
- ON - ORBIT PRACTICE OF COMPLEX REENTRY AND LANDING TASKS SIMULATED TO ONE - G ENVIRONMENT
- FERRY PILOT
- PREFLIGHT SIMULATION
- PREFLIGHT ADAPTATION

RELATED OPERATIONALLY IMPORTANT PROBLEMS

- DECREASED ABILITY TO EMERGENCY EGRESS
- VISUAL DYSFUNCTION
- IMPAIRED COGNITION

DECREASED ABILITY TO EMERGENCY EGRESS

Historical Background

The ability to perform physical work in response to either an emergency situation or as a part of one's daily routine is influenced by many physiological factors. The most obvious of these include: skeletal muscle strength, endurance and fatigue state, anaerobic capacity, orthostatic function, and posture and balance. Less obvious is the impact of decrements, in any of the above listed factors, on performance during or immediately after long duration exposure to microgravity. No identifiable studies have examined emergency egress, although many of the factors that are hypothesized to effect egress time have been studied.

Early observations in humans of significant decreases in muscle tone, muscle strength, muscular endurance, and physical work capacity were noted during the inflight and immediate postflight periods of a mission (Pestov, 1975, pp. 305-354 ; Thornton, 1977, pp. 191-197; Whedon, et al., 1977, pp. 164-174). These changes may well impact egress time, especially when one considers the astronaut would have to lift their body weight plus a 60 lb. suit out of the orbiter. Decrements in the strength of the arm and leg muscles of the Skylab astronauts were noted, with the decrement in arm extensors and flexors less than those of the legs (Thornton and Rummel, 1977, pp. 191-197; Nicogossian, et al., 1989). The leg strength loss averaged 20-25% from preflight values. This loss was felt to be related to the exercise modalities used during Skylab, but the extent of this relationship is unknown. Observations of minimal to moderate losses of nitrogen and postflight weight loss were consistent with muscle atrophy which then would lead to decreased muscular strength and increased muscular fatigue (Dietlein, 1977, pp. 408-418).

Loss of muscular strength and muscle atrophy was noted in the Robbins committee report as an identifiable change that occurs with extended duration space flight (Robbins Report, 1988, pp. 18, 45, 49). These changes may influence egress time; however, the impact of muscle loss on performance of astronauts during space flight was deemed as unclear by the committee since inflight activities (exclusive of EVA) require a minimal amount of muscular strength (Robbins Report, 1988, p. 46). Muscle atrophy and strength loss due to long term space flight was noted in A Strategy for Space Biology and Medical Science. (Goldberg Report, 1987, p. 146). EMG data collected during Skylab has indicated reduced muscular efficiency and increased susceptibility to fatigue. The committee suggested that the operational significance of these losses were uncertain as: "Methods used to evaluate muscle physiology have been rudimentary and have only been employed postflight . There have been no measures in space of typical muscle forces that occur...because of these limitations, we do not know the end point of space disuse atrophy or the time course with which it is reached." (Goldberg Report, 1987, pp. 146-147). The committee does suggest that missions lasting from several weeks to months will not likely lead to serious clinical inflight or postflight difficulties; however concerns regarding rapid egress were apparently not considered.

The life sciences research office of the Federation of American Societies for Experimental Biology published a committee report regarding research opportunities in muscle atrophy caused by space flight (FASEB - Muscle Atrophy, 1984). In the report it was noted that loss of skeletal muscle apparently has not compromised crew functions "...except, possibly during extravehicular activity and lunar surface EVA in Apollo 15... during the lunar surface activities two of the Apollo 15 crew developed cardiac arrhythmias." (FASEB - Muscle Atrophy, 1984, p. 21). The Federation committee noted that other changes caused by microgravity-induced muscular atrophy include a reduction of muscle volume, mass, exercise (aerobic) capacity, and neuromuscular coordination (FASEB - Muscle Atrophy, 1984, pp. 16-19).

Loss of anaerobic capacity will cause a decrement in any attempt to leave the area of the orbiter following exit. Loss in anaerobic capacity is expected due to one or a combination of both of the following mechanisms: 1) atrophy of the leg muscles, which would cause a decreased pool of stored anaerobic phosphagen energy (Edgerton, 1986, pp. 119-120), and 2) the buffering capacity of the blood will shift, especially with the use of isotonic saline to counter orthostatic intolerance. This will cause a more pronounced ventilatory response (shortness of breath) during high intensity exercise, and will lower the tolerance of the body to the high levels of lactic acid caused by a sprinting activity of more than ~200-300 meters.

Orthostatic hypotension induced by return from space flight has long been identified as a problem of concern operationally (Bungo, et al., 1985, pp. 56:985-990). Decreased orthostatic function induced during short term flights (2-14 days) is thought to be due primarily to fluid redistribution resulting in a decreased plasma volume (Bungo, et al., 1985, pp. 56:985-990; Nicogossian, et al., 1989). Oral consumption of a water and salt tablet combination to provide an "isotonic saline" for transient plasma volume expansion is utilized prior to landing in the Shuttle flights to help prevent orthostatic hypotension. This countermeasure does not prevent the manifestations of orthostatic hypotension in all cases, but is effective in reducing the severity of the signs and symptoms.

Degradation of posture and balance was observed on Skylab crew members and has been observed by the Soviets (Homick, et al., 1977, pp. 104-112; Gazenko, 1988). This degradation has lead to limitations of the ability of astronauts and cosmonauts to walk or run following short duration flights.

Recommendation for Monitoring

Appropriate monitoring for both muscular strength and fatigue changes pre- to postflight and inflight can be accomplished with the use of an isokinetic dynamometer. These tests could be accomplished on a weekly basis. The dynamometer should be capable of measuring both concentric (shortening) and eccentric (lengthening) muscle forces. A device capable of measuring only concentric forces was used to quantify strength changes pre- to postflight during the Skylab series of flights (Thornton, 1977, pp. 191-197). These measures should be taken at the hand and major joints. Appropriate monitoring for loss of anaerobic capacity pre- in- and postflight would include measuring, non-invasively, the changes in buffering capacity of the blood, and a test of anaerobic power performed on an exercise testing device on which the workload can be quantified (such as a cycle ergometer). Orthostatic tolerance inflight can be assessed by the measurement of the cardiovascular response to LBNP; pre- and postflight measurements can be obtained utilizing either a stand test, tilt table, or with LBNP. The effect of flight on posture and balance can be measured using a motion analysis device such as the Ariel™ system, on which locomotion activities can be digitized and quantified.

Anticipated Countermeasures

Appropriately prescribed exercise, LBNP inflight, saline countermeasure, "penguin suits", practice of complex sensorimotor tasks, preflight simulation, and adaptation.

Related Operationally Important Problems

Increased Muscular Fatigue/Decreased Muscular Strength
Altered Cardiovascular Function
Cardiac Dysrhythmias

Bogomolov V, Popova I, Egorov A and Kozlovskaya I. The Results of Medical Research During the 326-Day Flight of the Second Principal expedition on the Orbital Complex "MIR". Gazenko O, editor. *The Second US/USSR Joint Working Group Conference on Space Biology and Medicine*. Moscow: Institute of Medico-Biological Problems of the USSR Ministry of Health; 1986.

Bungo M, Charles J and Johnson P. Cardiovascular Deconditioning During Space Flight and the Use of Saline as a Countermeasure to Orthostatic Tolerance. *Aviat Space Med.* 1985; 56:985-990.

Dietlein L. "Skylab: A beginning." Johnston R, Dietlein L, editors. *Biomedical Results from Skylab*. Washington, D.C.: NASA; 1977:408-418.

FASEB. Talbot J, Fisher K, editors. *Research Opportunities in Muscle Atrophy*. Bethesda: Federation of American Societies for Experimental Biology; NASW 3924, 1985.

Goldberg J, et al. *A Strategy for Space Biology*. Washington, D.C.: National Academic Press; 1987.

Homick J, Reschke M and Miller E. "The effects of prolonged exposure to weightlessness on postural equilibrium." Johnston R, Dietlein L, editors. *Biomedical Results from Skylab*. Washington, D.C.: NASA; 1977.

Pestov I and Geratewohl S. "Weightlessness." Calvin M, Gazenko O, editors. *Foundations of Space Biology and Medicine*. Washington, D.C.: NASA; 1975:305-354.

Robbins F, et al. *Exploring The Living Universe: A Strategy for Space Life Sciences*. Washington, D.C.: NASA; 1988.

Thornton W and Rummel J. "Muscular deconditioning and its prevention in space flight." Johnston R, Dietlein L, editors. *Biomedical Results of Skylab*. Washington, D.C.: NASA; 1977:191-197.

Whedon G, Lutwak L, Raumbaut P, Whittle M, Smith M, Ried J, Leach C, Stadler C and Sanford D. "Mineral and nitrogen metabolic studies, experiment M071." Johnston R, Dietlein L, editors. *Biomedical Results from Skylab*. Washington, D.C.: NASA; 1977:164-174.

DECREASED ABILITY TO EMERGENCY EGRESS

HISTORICAL BACKGROUND

- LOSS OF LEG STRENGTH (20 - 25%) DURING MISSIONS OF UP TO 84 DAYS
- ANAEROBIC CAPACITY DECLINES DURING SPACEFLIGHT. THIS SHOULD ADVERSELY EFFECT SPRINTING OR OTHER HIGH INTENSITY ACTIVITIES
- ORTHOSTATIC HYPOTENSION IS INDUCED BY SPACEFLIGHT
- POSTURE AND BALANCE ARE DEGRADED. THESE DEGREDATIONS LIMIT THE ABILITY OF CREWMEMBERS TO WALK OR RUN

SIGNIFICANCE

- EXPOSURE TO MICROGRAVITY FOR PROLONGED PERIODS WILL INHIBIT THE CREWMEMBER'S ABILITY TO EGRESS RAPIDLY

RECOMMENDATIONS FOR MONITORING

- MONITOR
  - MUSCLE STRENGTH AND MUSCULAR FATIGUE (BOTH ECCENTRIC AND CONCENTRIC TYPE CONTRACTIONS)
  - ESTIMATED BUFFERING CAPACITY OF BLOOD
  - ORTHOSTATIC FUNCTION (BY LBNP)
  - POSTURE AND BALANCE

DECREASED ABILITY TO EMERGENCY EGRESS

BIOMEDICAL MONITORING AND COUNTERMEASURES

Presenter: GERALD TAYLOR / JSC

Date: DEC. 21, 1989

- **HYPOTHESIZED RESULTS AND SIGNIFICANCE**
  - LOSS OF MUSCLE STRENGTH
  - INCREASED MUSCULAR FATIGUE
  - LOWERING OF THE BUFFERING CAPACITY
  - ORTHOSTATIC HYPOTENSION UPON LANDING
  - POOR POSTURE AND BALANCE ON LANDING
  - A COMBINATION OF THESE CHANGES WILL LEAD TO A REDUCED ABILITY TO PERFORM EMERGENCY EGRESS

Presenter: GERALD TAYLOR / JSC

Date: DEC. 21, 1989

ANTICIPATED COUNTERMEASURES

- FLUID LOADING (SALINE OR OTHER ISOTONIC BEVERAGE)
- APPROPRIATELY PRESCRIBED EXERCISE
- LBNP INFLIGHT
- LBPP DURING LANDING AND EGRESS

DECREASED ABILITY TO EMERGENCY EGRESS

Presenter: GERALD TAYLOR / JSC

Date: DEC. 21, 1989

RELATED OPERATIONALLY IMPORTANT PROBLEMS

- INCREASED MUSCULAR FATIGUE / DECREASED MUSCULAR STRENGTH
- ALTERED CARDIOVASCULAR FUNCTION
- OSTEOPOROSIS AND FRACTURES

NORMAL BODILY FUNCTIONS

SLEEP DISORDERS

Historical Background

While sleep requirements vary from individual to individual, an individual's sleep requirements remain relatively constant over the short term. When the sleep/wake cycle is disrupted, however, it can result in decreased motivation to perform one's job. This is particularly true when the job requires a great deal of concentration (Coleman, 1986, p. 92). Such a situation could pose a serious risk to space station crewmembers whose safety often depends upon job performance.

Sleep loss, fatigue, and poor quality sleep have been reported on numerous U.S. and Soviet space missions (FASEB - Human Behavior and Performance, 1985; Frost, et al., 1977, p. 121; Bluth, 1986, pp. III-14, III-38, IV-28). These disruptions may be attributable to the absence of Zeitgebers (cues from the environment which give information about time), noise, scheduling difficulties, and to the psychological adjustment to an isolated, confined environment. Ground-based studies have shown that the absence of Zeitgebers tends to disrupt the sleep/wake cycle as well as certain behavioral, cognitive and personality variables (Matthews, 1985, p. 30). On board a space station there will be no natural Zeitgebers. Therefore we may expect crewmembers to experience changes in their sleep/wake cycle. Noise, too, has been noted on at least one mission as a cause of sleep disturbance (Lebedev, 1988, p. 45).

Scheduling difficulties have been problematic for both Soviet and U.S. space crews (Gazenko, et al., 1976, p. 2; Compton and Benson, 1983, p. 328). The Skylab IV astronauts indicated that they were not allowed enough uninterrupted pre-sleep time to "wind down". Additionally, many U.S. and Soviet crews have had to forego sleep in lieu of pressing operational or scientific tasks.

Informal reports also suggest that cosmonauts on long-duration flights have experienced disrupted sleep/wake cycles which may be attributable to the psychological adaptation to the isolated, confined environment (Lebedev, 1988, p. 49). The stress of isolation from one's normal sources of psychosocial support may lead to sleep disturbances.

The determination of sleep, work, and recreation schedules which would optimize human performance and adaptation to space was cited as a scientific objective in A Strategy for Space Biology and Medical Science (Goldberg Report, 1987, p. 177). The Robbins committee also indicated that an understanding of the effectiveness of various scheduling plans was essential for long duration space missions. (Robbins Report, 1988, p. 76).

Recommendations for Monitoring

Traditional polygraphic monitoring of sleep (e.g. EEG, ECG, EMG, EOG) would provide information regarding changes in the quality of sleep experienced by crewmembers on a daily basis. Radioimmunoassay analyses of salivary cortisol levels would provide information regarding the longer-term changes in circadian rhythms. Stress and mood measurements obtained via a computerized debrief would then provide information regarding the particular variables associated with any given sleep disturbance. Finally, "daytime" activity could be monitored using a wrist activity recorder. Information gathered with this device would provide an indicator of the impact of the disturbance on normal daily activity.

Anticipated Countermeasures

The absence of natural Zeitgebers could be compensated for by the introduction of artificial Zeitgebers. Light and dark cycles which naturally occur on Earth could be mimicked using the space station artificial lighting. Noise levels will be monitored by the station's Environmental Health System.

With the aid of crewmembers, scheduling difficulties may be alleviated by development of certain restrictions on scheduling. Flexibility to manipulate the schedule inflight to avoid work overload or work underload would also be helpful. Finally, those disturbances related to psychological adjustment to the station environment could be ameliorated by the invocation of many of the countermeasures identified for mood/motivation changes and psychophysiological stress.

Related Operationally Important Problems

Psychophysiological Stress
Interpersonal Conflict
Changes in Mood/Motivation
Impaired Cognition

Bluth J and Helppie M. *Soviet Space Stations as Analogs.* Washington, D.C.: NASA; NAGW-659,1986.

Coleman R. *Wide Awake at 3:00 A.M.* New York: W.H. Freeman and Company; 1986.

Compton D, Bensen C. *Living and Working in Space. Washington, D.C.: NASA; 1983.*

FASEB. Christensen J, Talbot J, editors. *Research Opportiunities in Human Behavior and Performance.* Bethesda: Federation of American Societies for Experimental Biology; NASW 3924, 1985.

Frost J, Shumate W, Salamy J and Booher C. "Experiment M133. sleep monitoring on Skylab." Johnston R, Dietlein L, editors. *Biomedical Results of Skylab.* Washington, D.C.: NASA; 1977:113-126.

Gazenko O, Gurovsky N, Nefyodov Y, Rudnyi N, Egorov B, Bryanov I, Gramenitsky P, Egorov A, Eryomin A and Zaloguev S. *Results of Biomedical Investigations of the ASTP Flight.* Moscow: USSR; 1976.

Goldberg J, et al. *A Strategy for Space Biology.* Washington, D.C.: National Academic Press; 1987.

Lebedev V. *Diary of a Cosmonaut: 211 Days in Space.* College Station: G.L.O.S.S. Company; 1988.

Matthews M. Circadian Rhythms and Long Duration Space Flight. *Psychological, Sociological, and Habitability Issues of Long-Duration Space Missions.* Houston: NASA/ JSC; NASA T-1082K, 1985.

Robbins F, et al. *Exploring the Living Universe/A Strategy for Space Life Sciences.* Washington, D.C.: NASA; 1988.

SLEEP DISORDERS

BIOMEDICAL MONITORING AND COUNTERMEASURES

Presenter: GERALD TAYLOR/JSC

Date: DEC. 21, 1989

HISTORICAL BACKGROUND

- SUBJECTIVE EVALUATIONS BY A NUMBER OF COSMONAUTS HAVE SHOWN THAT CHANGES IN SLEEP / WAKE SCHEDULES LED TO DECREMENTS IN THEIR EMOTIONAL AND PHYSIOLOGICAL STATES AND DECREASED THEIR WORK CAPACITY
- OCCASIONAL BOUTS OF INSOMNIA WERE REPORTED BY ALL THREE SKYLAB IV CREWMEMBERS
- SLEEP LOSS , POOR QUALITY SLEEP AND FATIGUE WERE REPORTED FROM THE GEMINI IV, APOLLO 7, 8, 13, 14, 15, AND STS-1 MISSIONS

SIGNIFICANCE

- SLEEP LOSS CAN AFFECT COGNITIVE PERFORMANCE AND MOOD, AND MAY INDUCE STRESS AND INTERPERSONAL CONFLICTS
- CRITICAL MISSION TASKS MAY BE AFFECTED BY SLEEP LOSS

RECOMMENDATIONS FOR MONITORING

- MONITOR
  - EKG, EEG, EMG, AND EOG PATTERNS (DURING SLEEP)
  - SALIVARY CORTISOL
  - MOOD AND STRESS MEASUREMENTS
  - "DAYTIME" ACTIVITY

SLEEP DISORDERS

Presenter: GERALD TAYLOR/JSC

Date: DEC. 21, 1989

- **HYPOTHESIZED RESULTS AND SIGNIFICANCE**
  - DISTURBANCES WILL BE FOUND IN TIME FOR SLEEP ONSET, QUALITY, AND QUANTITY OF SLEEP
  - THESE PARAMETERS WILL VARY DURING THE MISSION (e.g., SLEEP ONSET WILL BE MORE DELAYED EARLY IN THE MISSION)
  - CHANGES IN PATTERNS OF HORMONAL CONTROL WILL OCCUR
  - SLEEP DISTURBANCES WILL SHOW A STRONG CORRELATION TO MOOD AND STRESS STATES

ANTICIPATED COUNTERMEASURES

- MANIPULATION OF WORK / ACTIVITY SCHEDULES
- MANIPULATION OF LIGHT / DARK CYCLES
- INVOKE COUNTERMEASURES FOR CHANGES IN MOOD AND FOR PSYCHOLOGICAL STRESS (AS NEEDED)

SLEEP DISORDERS

BIOMEDICAL MONITORING AND COUNTERMEASURES

Presenter: GERALD TAYLOR/JSC

Date: DEC. 21, 1989

RELATED OPERATIONALLY IMPORTANT PROBLEMS

- PSYCHOPHYSIOLOGICAL STRESS
- INTERPERSONAL CONFLICT
- CHANGES IN MOOD / MOTIVATION
- IMPAIRED COGNITION

VISUAL DYSFUNCTION

Historical Background

Limited visual performance testing on Mercury, Gemini, and Apollo missions revealed few significant changes in visual function with the exception of constriction of visual field, changes in intraocular tension, and changes in the caliber of retinal vasculature. Some constriction of visual field was noted postflight as well as a decrease in unaided seven-meter visual acuity (although the latter was not statistically significant). Post-flight decrease in intraocular tension was significant and returned to preflight levels more slowly than expected. Retinal photography revealed no lesions, but showed some signs of decrease in the size of retinal vessels. The degree of constriction of retinal vascular was greater and persisted for a longer time than could be accounted for by the vasoconstrictive effect of atmospheric oxygen alone (Hawkins and Zieglschmid, 1975, p. 80). Although it was reported that early astronauts were able to see objects moving on the highway while in orbit, it was found performance was neither degraded nor improved during space flight and was within limits predicted by preflight measures of visual acuity. "The astronauts' reported ability to detect cars was probably due to dust clouds or shadows associated with traffic,which could significantly enlarge visual images." (Parker, et al., 1989, p. 168)

Anecdotal reports from Shuttle crewmembers describing decreases in visual performance, such as difficulty in reading checklists and changing focus within the cabin, led to additional visual performance testing . Near visual acuity was examined to measure changes in accommodation and other parameters affecting vision. Contrast sensitivity testing was conducted to provide a more accurate measure of general vision loss as well as insight into the possible physiological location and nature of vision changes. In-flight experiments revealed no statistically significant changes in contrast sensitivity (as a group) compared to the preflight baseline. Visual acuity was slightly worse but not statistically significant, and there was an apparent improvement in stereo acuity, although it was not significant. There was no significant group effect for cyclophoria, vertical phoria, or horizontal phoria, and there was no indication of individual changes in eye muscle balance . There were no significant changes in critical flicker frequency or eye dominance. Further research is needed; however, to determine if individual performance is repeatable (Task and Genco, 1987, p. 173-178). Additional measurements of intraocular pressure continued to show increases in IOP inflight.

Evidence of visual dysfunction during long duration space flight is limited to the study of light flashes conducted on Skylab and reports from Soviet investigations. Perceived light flashes during periods of dark adaptation were studied by Hoffman et al., (1977) during the Skylab 4 mission. "Although no performance disturbance has been associated with these light flashes, it is likely that the flashes mask transient visual stimuli." (Parker, et al., 1989, p. 170)

Subjective information from members of the Salyut-6 crew revealed no change in visual acuity at a distance. Reddening and tearing of the eyes, however, was reported in association with pressure and pain lasting 2-3 days. It is believed that these problems were the result of poor illumination of work stations and an increase in the brightness of sunlight. (Plyasova-Bakunina and Portnov, 1986, p. 74) Slight edema of the eyelids and moderate hyperemia of the eyeball was noticed the first few days inflight and continued for the duration of the flight. Incidence of postflight hyperemia of the conjunctiva and sclera (slight to moderate) was reported but disappeared in 3 to 4 days without treatment. Moderate congestive dilation of the retinal veins was apparent 6-8 hours postflight to 7 days after landing. No changes in retinal arterial vessels were noted. "Peripapillar edema of the retina was observed in one or, more frequently, both eyes, which gradually disappeared by day 7 postflight." (Plyasova-Bakunina and Portnov, 1986, p. 74)

Soviet investigators noted a 5 to 30 percent deterioration in visual function during the first days of flight, followed by a gradual restoration to preflight values. Contrast sensitivity exhibited a ten percent loss immediately after entry into microgravity and continued to decline to a 40 percent loss after five days. Even at these levels of change, it was concluded that the effect of spaceflight on visual function is relatively small. (Nicogossian, 1982, p.158) "...if [however] contrast sensitivity changes continued to develop during protracted exposure to weightlessness, as suggested by the work of Lazarev et al., (1981), the decrement could become operationally significant" (Parker, et al., 1989, p. 169).

Recommendations for Monitoring

It is hypothesized that the increase in intraocular pressure is caused by the headward shift of fluid during spaceflight, which can in turn result in changes in the physical characteristics of the eye (Vanderploeg, 1985 and Parker et al., 1989). In addition to causing a possible decrement in visual performance, increase in intraocular pressure could lead permanent loss of vision secondary to ocular pathologies, e.g., glaucoma and retinal vascular disease, if left untreated. Tonometry, funduscopy, and visual performance testing (visual acuity, contrast sensitivity, etc.) will be necessary to monitor visual dysfunction on long duration missions.

Related Operationally Important Problems

Decreased Ability to Perform High Precision Tasks
Decreased Ability to Emergency Egress
Impaired Cognition

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Plyasova-Bakunina I and Portnov V. "Sensory systems of prime crews on "Salyut-6" "Soyuz" space station complex.." Gurovskiy N, editor. *Results of Medical Research Performed on the "Salyut-6"-"Soyuz" Space Station Complex* Moscow: Nauka; 1986:163-165. TRANSLATED IN: USSR Space Life Sciences Digest, NASA CR-3922 (15), 1987; 13:74.

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Vanderploeg J and Ginsburg A. "Near vision acuity and contrast sensitivity (DSO)." Bungo M, Bagian T, Bowman M, Levitan B, editors. *Results of Life Sciences DSOs Conducted Aboard the Space Shuttle*. Houston: Space Biomedical Research Institute/NASA-JSC; 1987.

HISTORICAL BACKGROUND

- ANECDOTAL REPORTS FROM SHUTTLE CREWMEMBERS DESCRIBE INFLIGHT DECREMENTS IN NEAR VISION ACUITY AS INDICATED BY DIFFICULTY READING CHECKLISTS AND DIFFICULTY CHANGING FOCUS WITHIN THE CABIN

- LIMITED VISUAL PERFORMANCE TESTS ON U.S. AND SOVIET SPACEFLIGHTS INDICATE SIGNIFICANT CHANGES IN VISUAL FIELD, INTRAOCULAR PRESSURE, AND THE CALIBER OF RETINAL VASCULATURE

- VISUAL DYSFUNCTIONS EXPERIENCED ON SOVIET LONG-DURATION MISSIONS INCLUDE: REDDENING AND TEARING OF THE EYES, SLIGHT EDEMA OF THE EYELIDS, MODERATE HYPEREMIA OF THE EYEBALL AND PERIPAPILLAR EDEMA OF THE RETINA

HISTORICAL BACKGROUND - Continued

- ALTHOUGH TRENDS HAVE BEEN NOTED ON SHORT-DURATION MISSIONS, GROUP EFFECTS FOR CHANGES IN VISUAL ACUITY, EYE DOMINANCE, STEREOPSIS, CONTRAST SENSITIVITY, AND OTHER VISUAL FUNCTIONS WERE NOT SIGNIFICANT. FURTHER INVESTIGATION IS NECESSARY TO DETERMINE IF INDIVIDUAL RESULTS ARE SIGNIFICANT OR REPEATABLE

- IN PARTICULAR, IF CONTRAST SENSITIVITY CONTINUED TO DECLINE DURING LONG - DURATION SPACEFLIGHT, IT COULD BECOME OPERATIONALLY SIGNIFICANT

VISUAL DYSFUNCTION

BIOMEDICAL MONITORING AND COUNTERMEASURES

Presenter: GERALD TAYLOR / JSC

Date: DEC. 21, 1989

SIGNIFICANCE

- ACCURATE VISUAL PERCEPTION IS ESSENTIAL TO THE PERFORMANCE OF MISSION CRITICAL TASKS

RECOMMENDATIONS FOR MONITORING

- MONITOR
  - INTRAOCULAR PRESSURE (TONOMETRY)
  - RETINAL PHYSIOLOGIC RESPONSES TO SPACEFLIGHT
  - VISUAL PERFORMANCE - I.E., VISUAL ACUITY, CONTRAST SENSITIVITY, STEREOPSIS

VISUAL DYSFUNCTION

BIOMEDICAL MONITORING AND COUNTERMEASURES

Presenter: GERALD TAYLOR / JSC

Date: DEC. 21, 1989

- **HYPOTHESIZED RESULTS AND SIGNIFICANCE**

  - INCREASE IN INTRAOCULAR PRESSURE INFLIGHT, WHICH IF UNTREATED COULD LEAD TO PERMANENT LOSS OF VISION SECONDARY TO OCULAR PATHOLOGIES, e.g., GLAUCOMA AND RETINAL VASCULAR DISEASE
  - DECREMENT IN CONTRAST SENSITIVITY AND / OR NEAR VISION ACUITY

ANTICIPATED COUNTERMEASURES

- LBNP INFLIGHT
- PHARMACOLOGIC TREATMENT TO REDUCE INTRAOCULAR PRESSURE
- CORRECTIVE LENSES TO IMPROVE VISION

VISUAL DYSFUNCTION

BIOMEDICAL MONITORING AND COUNTERMEASURES

Presenter: GERALD TAYLOR / JSC

Date: DEC. 21, 1989

RELATED OPERATIONALLY IMPORTANT PROBLEMS

- DECREASED ABILITY TO PERFORM HIGH PRECISION TASKS
- DECREASED ABILITY TO EMERGENCY EGRESS
- IMPAIRED COGNITION

IMPAIRED THERMOREGULATION

Historical Background

There are few data regarding the effect of microgravity on thermoregulatory responses to physical work and exercise during and after flight (Convertino, 1990). Daily evaporative water losses during the three Skylab missions were estimated indirectly using mass and water-balance techniques (Leach, et al., 1978, pp. 430-436). Although it was expected that evaporative water losses would increase in the hypobaric environment of the Skylab spacecraft (~250 mmHg), the mean daily values of the nine crewmembers who averaged one hour of daily exercise decreased from 1750 ± 37 ml preflight to 1560 ± 26 ml during flight ($p < .05$). The results suggest that microgravity decreased sweat loss during exercise and possibly reduced insensible skin losses as well. The microgravity environment apparently promotes the formation of an observed sweat film on the skin surface during exercise by reducing convective flow and sweat drippings. This apparently results in high levels of sustained skin wetness that acts to suppress sweating (Leach, et al., 1978, pp. 430-436).

Data from groundbased studies showed excessive elevation in rectal temperature in seven men during 70 minutes of submaximal supine cycle ergometry (45-48% VO2 max) performed in an ambient temperature of 22°C after 14 days of simulated microgravity (Greenleaf, et al., 1980, pp. 72-78). This exercise hyperthermia was greater than the pre-bedrest ambulatory control level, suggesting a reduced capacity to dissipate heat. No significant differences in total body sweat production were observed, suggesting an inhibition of sweating from the same core temperature stimulus. Thus, data from flight and groundbased models indicate that microgravity causes some impairment in thermoregulation during exercise which could be limiting to work performance of extended duration such as EVA. However, this problem may be removed or mitigated during work or exercise inside the spacecraft habitat area by use of high volume air movement in the area of the exercise equipment.

The space suit currently used by the United States Space Program has a liquid cooled garment capable of sustaining work rates of from 400-500 kcal/hr (Horrigan et al., 1989, pp. 121-135). The average energy expenditure during Skylab EVAs was 238 kcal/hr. The highest energy cost associated with a Skylab EVA was 500 kcal/hr (Waligora, et al., 1977, pp. 395-399). The time the crew member was at this level was not reported. No thermal related problems were reported during Skylab EVAs. The average shuttle EVA has required 197 kcal/hr (Horrigan et al., 1989, pp. 121-135). Soviet data indicates EVA activities have required up to 840 kcal/hr during brief high intensity work bouts. The mean ($\pm$ SD) metabolic cost for 48 Soviet EVAs was 275 $\pm$ 50.1 kcal/hr (Barer, 1989).

Recommendations for Monitoring

Appropriate monitoring for, and prevention of thermoregulatory problems that would occur inside of the spacecraft include monitoring of the ambient temperature and humidity, monitoring of air flow through the exercise facility, and occasional measurement of the crew member's core temperature response to a long (~1 hour) exercise bout. Attainment of body mass before and after this exercise bout will yield a crude estimate of sweat volume loss. Monitoring of an astronaut's metabolic responses during EVA will continue as in previous missions.

Anticipated Countermeasures

Increased air flow to areas where exercise is being performed, extra fluid and electrolyte replacement during activity, ground controlled pacing of high intensity EVA activities, continued refinement of suit and tool design.

Related Operationally Important Problems

Decreased Ability To Perform Long Duration Tasks

Barer A. Extravehicular Activity Medical Support. *8th IAA Symposium "Man in Space".* Tashkent; USSR, 1989:1-8.

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Leach C, Leonard J, Raumbaut P and Johnson P. Evaporative Water Loss in Man in a Gravity-free Environment. *Appl Physiol.* 1978; (45):430-436.

Waligora J and Horrigan D. "Metabolic cost of extravehicular activities." Johnston R, Dietlein L, editors. *Biomedical Results of Skylab.* Washington, D.C.: NASA; 1977:395-399.

HISTORICAL BACKGROUND

- THERE ARE FEW DATA REGARDING THE EFFECT OF MICROGRAVITY ON THERMOREGULATORY RESPONSES TO PHYSICAL WORK AND EXERCISE DURING AND AFTER FLIGHT
- DURING ONE HOUR OF EXERCISE, EVAPORATIVE WATER LOSSES OF THE NINE SKYLAB CREWMEMBERS DECREASED FROM 1750 $\pm$ 37 ML PREFLIGHT TO 1560 $\pm$ 26 ML DURING FLIGHT
- THE MICROGRAVITY ENVIRONMENT PROMOTES THE FORMATION OF AN OBSERVED SWEAT FILM ON THE SKIN SURFACE DURING EXERCISE BY REDUCING CONVECTIVE FLOW AND SWEAT DRIPPINGS. THIS APPARENTLY RESULTS IN HIGH LEVELS OF SUSTAINED SKIN WETNESS THAT ACTS TO SUPRESS SWEATING
- DATA FROM GROUNDBASED STUDIES SHOWED EXCESSIVE ELEVATION IN RECTAL TEMPERATURE MEN DURING EXERCISE AFTER 14 DAYS OF SIMULATED MICROGRAVITY. THIS EXERCISE HYPERTHERMIA WAS GREATER THAN THE PRE-BEDREST AMBULATORY CONTROL LEVEL SUGGESTING A REDUCED CAPACITY TO DISSAPATE HEAT.

IMPAIRED THERMOREGULATION

BIOMEDICAL MONITORING AND COUNTERMEASURES

Presenter:	Date:
GERALD TAYLOR/JSC	DEC. 21, 1989

SIGNIFICANCE

- IMPAIRED THERMOREGULATORY RESPONSE COULD BE LIMITING TO WORK PERFORMANCE OF EXTENDED DURATION

RECOMMENDATIONS FOR MONITORING

- **MONITOR**
  - AMBIENT TEMPERATURE AND HUMIDITY
  - AIR FLOW THROUGH THE EXERCISE FACILITY
  - CORE TEMPERATURE RESPONSE TO A LONG (1 HOUR) EXERCISE BOUT
  - ASTRONAUTS THERMAL RESPONSES DURING EVA
  - CHANGES IN BODY MASS DUE TO EVA AND EXERCISE (CRUDE ESTIMATE OF SWEAT PRODUCTION)

IMPAIRED THERMOREGULATION

BIOMEDICAL MONITORING AND COUNTERMEASURES

Presenter: GERALD TAYLOR/JSC

Date: DEC. 21, 1989

- ## HYPOTHESIZED RESULTS AND SIGNIFICANCE

  - THE PHYSIOLOGICAL MECHANISMS USED TO DISSIPATE HEAT WILL BE INHIBITED. MONITORING WILL ALLOW IMPLEMENTATION OF APPROPRIATE COUNTERMEASURES TO REDUCE THE MAGNITUDE OF THESE CHANGES

ANTICIPATED COUNTERMEASURES

- INCREASED AIR FLOW TO AREAS WHERE EXERCISE IS BEING PERFORMED
- FLUID AND ELECTROLYTE REPLACEMENT DURING ACTIVITY
- EXTERNAL PACING OF HIGH INTENSITY EVA ACTIVITIES
- CONTINUED REFINEMENT OF LIQUID COOLED GARMENTS AND SPACESUITS

RELATED OPERATIONALLY IMPORTANT PROBLEMS

- DECREASED ABILITY TO PERFORM LONG DURATION TASKS

BIOMEDICAL MONITORING
AND COUNTERMEASURES
PROGRAM

SPACE STATION FREEDOM

GERALD TAYLOR, Ph.D

DECEMBER 21, 1989

MENTAL AND SOCIAL WELL-BEING

CHANGE IN MOOD/MOTIVATION

Historical Background

The space station era is expected to bring many changes to the U.S. space program. Unlike prior U.S. space programs, long duration crew rotations are expected to be routine, non-career astronauts will be more plentiful and all crews are expected to be culturally heterogeneous. For all these reasons we must draw not only from U.S. experiences, but from Soviet and analog experiences to extrapolate the potential effects of the space station environment on the mood and motivation of its crews.

It is clear that Soviet cosmonauts have experienced mood disturbances on long duration flights. In Diary of a Cosmonaut, Valentin Lebedev (1988) recorded that on the 200th day of their mission he "looked in the mirror and was dismayed - my face was covered with red blemishes caused by nerves, and my back is peeling. We're pretty depressed." Some cosmonauts experienced "space-phobia" upon conducting EVAs. In the words of one cosmonaut, "To be honest: I didn't care for it. I was scared. Below us was Earth and we felt our moving through space" (Bluth and Helppie, 1986, p. II-46). Most cosmonauts reported missing their families a great deal and the stresses associated with long-term spaceflight seem to have taken their toll. One cosmonaut experienced a "sudden personality change" which was found to be caused by "excessive doses of sleeping pills" which he took because he was having great difficulty sleeping (Bluth and Helppie, 1986, p. III-38). The Robbins report indicated that informal reviews of mission reports and interviews with space crews and ground personnel revealed that a variety of behavioral disturbances including mood fluctuation, boredom, irritability, fatigue, anxiety, motivational shifts, crew conflicts, and sleep loss have occurred on U.S. space missions as well (Robbins Report, 1988, p. 72).

The Soviet Psychological Support Team has identified two stages of response to the space station environment. According to their findings, the first stage lasts for the first two to six weeks of spaceflight and is characterized by adaptation to a new environment, a new schedule, and new work activities (Bluth and Helppie, 1986, p. IV-30). Both Skylab astronauts and Soviet cosmonauts on long-duration missions have expressed anxiety over their job performance during this time period (Compton and Benson, 1983, pp. 326-330; Lebedev, 1988, p. 42). The second stage of psychological adaptation identified by the Soviets comprises the remainder of the flight and is characterized by manifestations of deprivation effects. The monotony of routine activities and the influence of prolonged isolation and confinement begin to cause episodes of depression, irritability and sleep disorders. During this stage, U.S. and Soviet crews have requested increased stimulation in the form of both increased workloads and increased social contacts (Compton and Benson, 1983, pp. 310-311; Bluth and Helppie, 1986, p. III-87). A similar pattern of adaptation has been noted in analog environments. Rohrer conducted a review of Antarctic and submarine literature and found that there were three stages of reaction to conditions of isolation. According to Kanas' summarization of Rohrer's report:

> The first stage is a period of heightened anxiety which occurs during the first few days and is a function of the degree of danger that is perceived by each individual....The second stage is a period of depression. This stage occupies the greatest block of time and occurs as the men settle down and begin routine duties. There is a steady increase in depressed affect, which Rohrer believed was a reaction to the loss of accustomed social roles due to isolation. The final stage is a period of anticipation. This occurs at the end of the mission and is characterized by increased affect expression...decreased work performance, and the emergence of aggression (Kanas, 1985).

Thus, while the length and number of the stages of adaptation to isolated and confined environments are debated, there appears to be a consensus that a period of anxiety is followed by a period of depression with a possible anticipatory phase near the end of the isolation.

The Soviets have, since the beginning of their space program, utilized social and psychological testing and training preflight and have employed the use of a Psychosocial Support Team as an integral part of their ground support crew. Their stance is voiced by Beregovoe (who is in charge of cosmonaut crew training): "Most men die psychologically before they die physically. They are not prepared" (Bluth and Helppie, 1986, p. III-97). The Psychological Support Team strives to mitigate some of the negative effects of isolation and confinement by providing opportunities for social interaction with family, friends, colleagues, popular figures, political figures, etc. They also uplink television broadcasts of news shows in order to help the cosmonauts keep in touch with activities on Earth. The ultimate purpose of the team is to "create for them a normal life in a communal apartment." (Personal Communication, 1989)

Recommendations for Monitoring

Potential means for monitoring mood and motivation inflight include computerized mood survey responses, voice stress analysis, task sampling, productivity tracking, responses to structured interviews with flight surgeons, debriefing sessions with crew families, and correlations of mood and motivation measures with measures of cognitive workload and stress. The mood survey would provide a subjective measure and would be available on the crewmember's stateroom computer to allow for privacy. Voice stress analysis could be conducted unobtrusively on open communication lines to get an objective check on the survey responses. Task sampling and productivity tracking would provide information regarding motivation. Based on Skylab experience it will be necessary to take into consideration inflight changes to the flight data file and work interruptions. Responses to structured interviews with flight surgeons and information gained through regular family debrief sessions will provide a more flexible format for the subjective evaluation of the crewmember's mood and motivation. Correlations with measures of workload and stress are necessary to determine appropriate countermeasures.

Anticipated Countermeasures

It is anticipated that a formal Psychosocial Support Program would comprise the greatest countermeasure for changes in mood and motivation. Such a program would involve use of encrypted audio/visual downlink capability for private communications between crewmembers and their families. As we learned from Skylab, it may be necessary, on occasion, to use the private downlink for crew-to-ground communications as well. The importance of such downlinks is that they would provide a substitute for the normal social interactions which will be otherwise quite limited. Additionally, it would provide a means for psychological or psychiatric intervention should the need arise.

Other potential countermeasures include formal psychological/practical support for the families of crewmembers. A formal support program for the families would not only relieve some of the stress placed on the family system by the extraction of one of its members, but would also alleviate some of the concerns a crewmember might have for his/her family's well-being. In addition, means for altering work design (such as job rotation) may prove an effective means for circumventing monotony among crews on long-duration missions. Alterations in work/rest/recreation schedules may be a logical response to mood/motivation changes as well. Finally, it may prove helpful to train crewmembers in recognition of mood disorders and means for countering them on their own initiative.

Related Operationally Important Problems

Sleep Disorders
Impaired Cognition
Interpersonal Conflict
Psychological Stress

Bluth J and Helppie M. *Soviet Space Stations as Analogs.* Washington, D.C.: NASA; NAGW-659, 1986.

Compton D and Bensen C. *Living and Working in Space.* Washington, D.C.: NASA; 1983.

Kanas N. Psychosocial Factors Affecting Simulated and Actual Space Missions. *Aviat Space Environ Med.* 1985; 56:806-811.

Lebedev V. *Diary of a Cosmonaut: 211 Days in Space.* College Station: G.L.O.S.S. Company; 1988.

Personal Communication. *One Year In Space.* TRANSLATED FROM: Literaturnaya Gazeta, January 4, 1989.

Robbins F, et al. *Exploring the Living Universe/A Strategy for Space Life Sciences.* Washington, D.C.: NASA; 1988.

HISTORICAL BACKGROUND

- ANECDOTAL INFORMATION AND PUBLISHED DIARIES OF COSMONAUT EXPERIENCES INDICATE THAT MOOD DISTURBANCES HAVE BEEN A COMMON PROBLEM ON LONG DURATION MISSIONS

- ONE COSMONAUT EXPERIENCED A SUDDEN PERSONALITY CHANGE DUE TO "EXCESSIVE DOSES OF SLEEPING PILLS" HE HAD TAKEN BECAUSE HE WAS UNABLE TO REST

- ON A 96-DAY SOVIET MISSION, MOOD DISTURBANCES CAUSED COSMONAUTS TO REPORT THAT THEY FELT TIRED NOT ONLY AT THE END OF A WORKDAY BUT EVEN SHORTLY AFTER WAKING

- EPISODES OF TRANSIENT MOOD DISTURBANCES HAVE OCCURRED ON U.S. SPACEFLIGHTS (e.g., IRRITABILITY, DEPRESSION). THESE MAY BE EXPECTED TO BE EXACERBATED BY LONG DURATION ISOLATION AND CONFINEMENT

HISTORICAL BACKGROUND - Continued

- SSF CREWMEMBERS WILL BE ISOLATED FROM NORMAL SOCIAL SUPPORTS (e.g., FAMILY, FRIENDS, COLLEAGUES)
- STUDIES HAVE SHOWN A DIRECT AND SIGNIFICANT INVERSE RELATIONSHIP BETWEEN SOCIAL SUPPORT AND DEPRESSION

SIGNIFICANCE

- MOOD DISTURBANCES AND MOTIVATION DECREMENTS COULD RESULT IN DECREASED EFFICIENCY AND PRODUCTIVITY AND MAY POSE SAFETY HAZARDS

RECOMMENDATIONS FOR MONITORING

- MONITOR
  - RESPONSES TO MOOD SURVEY ON CREW DEBRIEF SOFTWARE (MOOD) - OBTRUSIVE
  - VOICE STRESS (MOOD) - UNOBTRUSIVE
  - TASK SAMPLING (MOTIVATION)
  - PRODUCTIVITY TRACKING (MOTIVATION)
  - RESPONSES TO STRUCTURED INTERVIEWS WITH FLIGHT SURGEON (MOOD AND MOTIVATION)
  - REGULAR FAMILY DEBRIEF (MOOD AND MOTIVATION)
  - CORRELATIONS WITH COGNITIVE WORKLOAD AND STRESS MEASURES

CHANGE IN MOOD / MOTIVATION

BIOMEDICAL MONITORING AND COUNTERMEASURES	
Presenter: GERALD TAYLOR, PhD.	Date: DEC. 21, 1989

HYPOTHESIZED RESULTS AND SIGNIFICANCE

- IRRITABILITY WILL INCREASE AS MISSION PROGRESSES
- OPERATIONALLY RELEVANT DECLINES IN MOOD AND MOTIVATION WILL OCCUR AS THE MISSION CONTINUES

ANTICIPATED COUNTERMEASURES

- INCREASED RECREATION TIME
- FORMAL PSYCHOLOGICAL SUPPORT PROGRAM FOR CREW
  - ENCRYPTED AUDIO / VISUAL DOWNLINK FOR PRIVATE COMMUNICATION WITH FAMILY (AND GROUND CREW AS NEEDED)

ANTICIPATED COUNTERMEASURES - Continued

- REGULAR INFLIGHT CONTACT WITH HOME, FRIENDS, CHURCH, ETC.
- GROUND BASED TEAM FOR BACKUP PSYCHOLOGICAL / PSYCHIATRIC INTERVENTION

- FORMAL PSYCHOLOGICAL / PRACTICAL SUPPORT FOR FAMILIES
- ALTER WORK DESIGN (e.g., JOB ROTATION) TO ALLOW DIVERSITY OF EXPERIENCE
- TRAINING IN IDENTIFYING AND COUNTERING MOOD DISORDERS
- MANIPULATE WORK / REST / RECREATION CYCLES

CHANGE IN MOOD / MOTIVATION

BIOMEDICAL MONITORING AND COUNTERMEASURES

Presenter: GERALD TAYLOR, PhD.

Date: DEC. 21, 1989

RELATED OPERATIONALLY IMPORTANT PROBLEMS

- SLEEP DISORDERS
- IMPAIRED COGNITION
- INTERPERSONAL CONFLICT
- PSYCHOPHYSIOLOGICAL STRESS

IMPAIRED COGNITION

Historical Background

Aboard the Space Station Freedom, each crewmember's ability for normal cognitive functioning will be essential. Such tasks as docking with a resupply vessel or conducting EVAs will require adequate cognitive performance. There are, however, many factors which are known to occur in space travel that may negatively affect cognitive function. Among these are fatigue sleep loss, emotional stress, disorientation, depression, mood disturbance, over-extended tasking, excessive noises and impaired sensorimotor input (time distortion, visual dysfunction) (Robbins Report, 1988, p. 72; Compton & Benson, 1983, pp. 295-334). Additionally, there are risks of illness, exposure to environmental toxins, and possible effects of medications - any of which could significantly impact cognitive ability.

A Soviet investigation of the "Motor Efficiency of Cosmonauts Inflight" has shown that visual tracking abilities declined and reaction time increased in both crewmembers of the 18-day Soyuz 9 flight. (Ivanov, et al., 1972, p. 5) These measurements were obtained by embedding a device in "craft orientation control, transmission of Morse characters by telegraph, and others" that recorded simple reaction time, reaction to three alternative options, and pursuit tracking of signals. The report also presented several incidents which have occurred on both U.S. and Soviet spaceflight which the report attributed to impaired psycho-motor ability (e.g. difficult or failed attempts at docking). Additionally, they report an incident in which a cosmonaut required "twice as much time for ship orientation movements in the early orbits as he had on the ground and on later orbits." (Ivanov, et al., 1972, p. 9)

Furthermore, anecdotal information suggests that, "while overall performance has been remarkably good, decrements have been evidenced in experimental errors, lost data, equipment mishandling, and a variety of behavioral disturbances..." (Robbins Report, 1988, p. 72) This information led both the Robbins and Goldberg committees to report that the influence of the various aspects of the space environment on cognitive functions warrant investigation. (Goldberg Report, 1987, p. 177; Robbins Report, 1988, p. 44)

Recommendations for Monitoring

Cognitive function can be monitored using both embedded decrement-sensitive psychomotor tasks in routine work, and analysis of video/audio transmissions of task performance. The embedded measurements could be accomplished using devices which would record reaction time, accuracy of visual tracking and pattern recognition, and efficiency of short-term memory recall. These devices could be attached to cupola, RMS, or experiment hardware which is operator-manipulated. These type of measurements have been successfully obtained by Soviet investigators. (Ivanov, et al., 1972, p. 2) Those tasks which are critical, but do not require manipulation of a computer or hardware, may be monitored via embedded tasks as well. For example, the U.S. Air Force has employed the use of embedded tasks in voice communications between fighter pilots and ground control to monitor mental performance under heavy workloads.

If it is made known to the crew, that embedded measures are being monitored for the purpose of assessing changes in cognitive function, task sampling will also need to be conducted. Sampling the completion of a particular task and comparing performance of the task against known normal performance parameters (e.g., time required to complete, number of errors, etc.) would provide information regarding decrements in cognitive performance. Additionally, an irregular sampling schedule would ensure that enhanced motivation to perform the task was not confounding the data derived by the other monitoring techniques. Analysis of audio/video transmissions of various tasks being performed on board could be accomplished by using a motion analysis device such as the Ariel ™ system which can digitize and quantify locomotion activities. These values could then be compared to known parameters for that task. Comparisons to information gained from the stress, sleep, mood/motivation, and interpersonal conflict monitoring activities should also be taken into consideration in order to determine which factors may be contributing to changes in cognitive function.

Anticipated Countermeasures

- Training on the use of cognitive feedback
- Feedback to individual crewmembers regarding their cognitive function and thereby allowing the crewmember to alter his/her own environment, work/rest schedule, etc.
- Train crewmembers to recognize cognitive-sensitive tasks and to interpret for themselves cognitive decrements
- Redesign workloads or task scheduling
- Reduce physical workload

•Re-allocate tasks to reduce metal workload
•If monitoring of related operationally important problems indicates that those other factors may be contributing to the impairment, invoke countermeasures which mitigate those problems.

<u>Related Operationally Important Problems</u>

Visual Dysfunction
Psychophysiological Stress
Sleep Disorders
Mood/Motivation Change
Decreased Ability to Perform High Precision Tasks

Compton D and Bensen C. *Living and Working in Space. Washington, D.C.: NASA; 1983.*

Goldberg J, et al. *A Strategy for Space Biology*. Washington, D.C.: National Academic Press; 1987.

Ivanov Y, Popov V and Khachtur'yants L. Motor Efficiency of a Cosmonaut in Flight. *Processing of Medical Information and Assessment of Work Capacity in Space Flight*. Arlington: Joint Publications Research Service; JPRS-57417,1972. TRANSLATED IN: Kosmicheskiye Issledovaniya, 1972; 4:604-619.

Robbins F, et al. *Exploring the Living Universe/A Strategy for Space Life Sciences*. Washington, D.C.: NASA; 1988.

IMPAIRED COGNITION

Presenter: GERALD TAYLOR, Ph.D.

Date: DEC. 21, 1989

HISTORICAL BACKGROUND

- SOVIET STUDIES OF INFLIGHT COGNITIVE ABILITY USING EMBEDDED DEVICES IN CONTROL INSTRUMENTS SHOWED THAT COMPARED TO THEIR REACTION TIMES PREFLIGHT, THE REACTION TIME OF COSMONAUTS WAS INCREASED BY 70% UNDER CONDITIONS OF PROLONGED SPACEFLIGHT

- ALTHOUGH OVERALL PERFORMANCE ON U.S. MISSIONS TO DATE HAS BEEN QUITE GOOD, THERE HAVE BEEN OCCURRENCES OF DECREMENTS IN THE FORM OF EQUIPMENT MISHANDLING, EXPERIMENTAL ERRORS, etc., WHICH MAY HAVE BEEN PARTLY DUE TO DECREMENTS IN COGNITIVE ABILITY

- MANY THINGS WHICH ARE KNOWN TO OCCUR IN SPACEFLIGHT (e.g., SLEEP LOSS, EMOTIONAL STRESS, etc.) ARE KNOWN TO CAUSE DECREMENTS IN COGNITIVE ABILITY ON EARTH

- BOTH THE GOLDBERG AND ROBBINS COMMITTEES HAVE SUGGESTED THAT CHANGES IN COGNITIVE FUNCTION ON LONG DURATION MISSIONS SHOULD BE INVESTIGATED

IMPAIRED COGNITION

BIOMEDICAL MONITORIN
AND
COUNTERMEASURES

Presenter: GERALD TAYLOR, Ph.D.

Date: DEC. 21, 1989

SIGNIFICANCE

- WHILE THERE IS LITTLE SCIENTIFIC DATA ON COGNITION IN SPACEFLIGHT, GROUND - BASED STUDIES AND ANECDOTAL INFORMATION SUGGEST THAT IT IS LIKELY TO OCCUR
- IF COGNITIVE FUNCTION DECLINES, THERE IS AN INCREASED RISK OF ERROR FOR HIGHLY CRITICAL TASKS (e.g., DOCKING WITH RESUPPLY SPACECRAFT, EVA'S, etc.)

IMPAIRED COGNITION

BIOMEDICAL MONITORING AND COUNTERMEASURES

Presenter:	Date:
GERALD TAYLOR, Ph.D.	DEC. 21, 1989

RECOMMENDATIONS FOR MONITORING

- **MONITOR** (VIA EMBEDDED PSYCHO - MOTOR TASKS)
  - SHORT - TERM MEMORY RECALL
  - VISUAL TRACKING ABILITY
  - PATTERN RECOGNITION ABILITY
  - REACTION TIME

- **HYPOTHESIZED RESULTS AND SIGNIFICANCE**
  - DECREMENTS WILL BE OBSERVED IN ONE OR MORE OF THE PARAMETERS MONITORED AND THE DEGREE OF DECREMENT WILL VARY WITH TIME.
  - DECREMENTS IN ANY OF THE MONITORED PARAMETERS IS INDICATIVE OF A DECREMENT IN OVERALL COGNITIVE FUNCTION

ANTICIPATED COUNTERMEASURES

- COGNITIVE FEEDBACK
- REDESIGN TASK SCHEDULE OR WORKLOAD
- RE - ALLOCATE TASKS TO REDUCE MENTAL WORKLOAD
- INVOKE COUNTERMEASURES FOR CONTRIBUTING RELATED PROBLEM (e.g., SLEEP LOSS, MOOD DISTURBANCE, etc.)

IMPAIRED COGNITION

BIOMEDICAL MONITORING AND COUNTERMEASURES

Presenter: GERALD TAYLOR, Ph.D. | Date: DEC. 21, 1989

RELATED OPERATIONALLY IMPORTANT PROBLEMS

- VISUAL DYSFUNCTION
- PSYCHOPHYSIOLOGICAL STRESS
- SLEEP DISORDERS
- MOOD / MOTIVATION CHANGES
- DECREASED ABILITY TO PERFORM HIGH PRECISION TASKS

INTERPERSONAL CONFLICT

Historical Background

The importance of group cohesion in an isolated, confined environment cannot be overestimated. Many nominal and emergency operations would require coordinated crew efforts for safe completion. Additionally, a conflict could escalate to the point where the conflict itself posed a hazard to crew health. Based on Soviet and U.S. experience, complete absence of interpersonal conflicts between crewmembers is probably an unattainable goal for long duration space missions. However, it is feasible to mitigate the conflicts which are likely to occur.

Inflight experience and ground-based studies have shown that issues which might otherwise seem trivial become exaggerated under conditions of isolation and confinement. One extreme example of such an incident resulted in the murder of an Antarctic expedition crewmember (Bluth, 1982, p. 8-52). While this was an extreme case, a number of studies have shown that among crews at various Antarctic stations, symptoms of anxiety, depression, insomnia and hostility were increased by up to 40 percent by the end of a wintering-over period (Bluth, 1982, p. 8-52). Additionally, instances of occasional hostile exchanges between space and ground crews have occurred in both the U.S. and Soviet space programs. Such hostile exchanges between crewmembers and ground support have been noted in numerous analog studies, suggesting it may be a common reaction to isolated and confined environments.

Instances of interpersonal conflict are known to have occurred on many U.S. and Soviet space missions (FASEB - Human Behavior, 1985, pp. 9, 25; Goldberg Report, 1987, p. 167; Robbins Report, 1988, p. 72; Bluth and Helppie, 1986, pp. III-96, III-101, IV-35, IV-54; Bluth, 1982, pp. 8-53 - 8-54; Lebedev, 1988, p. 39; Personal Communication, 1989, pp. 5-6). These incidents have occurred even among relatively homogeneous crews which have been selected for their compatibility. When cultural backgrounds of crewmembers have been more heterogeneous, the situation has been even further complicated (FASEB - Human Behavior, 1985, p. 25). As one Czech cosmonaut noted, both language and value differences can be problematic and often result in misunderstandings (Bluth, 1982, pp. 8-53 - 8-54).

While many feel that scientific communities are completely objective and, therefore, without cultural bias, there is evidence to suggest the contrary. For example, one joint scientific effort between American and Japanese high energy physicists resulted in conflicts and misunderstandings which were directly attributable to cultural differences (Traweek, 1988, pp. 154-155). Notably, all the scientists spoke fluent English and were not collected into an isolated and confined environment. While great benefits can be reaped from the work of a culturally diverse group, formation of such groups is often problematic.

The effects of long-duration spaceflight on interpersonal relationships were cited by the Robbins committee report as being an area which needs investigation. The report also called for the development of guidelines for conflict resolution inflight and for preflight training in communication and conflict resolution (Robbins Report, 1988, pp. 9, 44, 71). A Strategy for Space Biology and Medical Science, developed by the Goldberg committee, identified a scientific goal which called for the identification of the "group and organizational factors that influence the performance and behavioral stability of individuals and the entire crew in the space environment" (Goldberg Report, 1987, p. 180). The life sciences research office of the Federation of American Societies for Experimental Biology (FASEB) published a committee report in which it was suggested that flight- and groundcrews of the space station might benefit from training in social sensitivity, team building, cohesiveness, and interpersonal communication (FASEB - Human Behavior, 1985, p. 49).

Recommendations for Monitoring

Potential means for monitoring interpersonal conflict include computerized responses to a generic crew debrief. This debrief would be accessed by each crewmember via his/her stateroom computer to allow for privacy. Additionally, access to information gathered by the debrief would be restricted to the individual crewmember and a member of the ground-based Psychosocial Support Team. Real-time analysis of audio content would be another means of monitoring interpersonal conflict and would have the benefit of being unobtrusive. Further information could be gained from crewmembers and ground support via informal reports.

Anticipated Countermeasures

It is anticipated that preflight training would be the primary countermeasure to interpersonal conflicts. Training in conflict resolution, problem solving, group dynamics, and cross-cultural differences would be integrated into the whole crew training for a minimum of one year prior to flight. A conflict management process would be defined prior to the mission and crews would be selected for compatibility. Inflight, regular crew meetings would serve as a forum for resolving conflicts. Additionally, ground-based social scientists would be available for consultation as necessary.

Related Operationally Important Problems

Sleep Disorders
Changes in Mood/Motivation
Psychophysiological Stress

Bluth B and Helppie M. *Soviet Space Stations as Analogs.* Washington, D.C.: NASA; NASA Grant NAGW-659, 1986.

Bluth B. The Human Spirit In Space. *Making Space Work for Mankind; Proceedings of the 19th Space Congress.* Cape Canaveral: Council of Technical Societies; 1982.

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Robbins F, et al. *Exploring the Living Universe/A Strategy for Space Life Sciences.* Washington, D.C.: NASA; 1988.

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HISTORICAL BACKGROUND

- THE CHIEF OF CREW TRAINING IN THE U.S.S.R. REPORTED THAT ON ALL FOUR SALYUT 6 LONG - DURATION MISSIONS CREWS DEVELOPED SIGNS OF INTERPERSONAL HOSTILITY
- HOSTILE EXCHANGES HAVE OCCURRED BETWEEN CREW AND GROUND CONTROLLERS ON BOTH U.S. AND SOVIET SPACE MISSIONS. ONE SUCH SOVIET INCIDENT RESULTED IN THE CREW "DELIBERATELY CUTTING OFF INCOMING COMMUNICATIONS FOR SEVERAL HOURS OR LONGER"
- ONE SOVIET CREW WHICH HAD ALREADY BEEN READIED FOR FLIGHT HAD TO BE REPLACED BECAUSE OF TENSION BETWEEN CREWMEMBERS
- ANECDOTAL INFORMATION FROM U.S. SPACEFLIGHTS AND REPORTS FROM SOVIET FLIGHTS INDICATE THAT MISUNDERSTANDINGS OF A CULTURAL NATURE FREQUENTLY OCCUR AMONG MULTI-NATIONAL CREWS.

HISTORICAL BACKGROUND - Continued

- INDUSTRY USE OF TRAINING PROGRAMS IN CONFLICT RESOLUTION AND CROSS-CULTURAL INTERACTIONS HAS SHOWN THAT SUCH PROGRAMS GREATLY INCREASE THE RATE OF SUCCESSFUL GROUP INTERACTIONS

SIGNIFICANCE

- FRICTION AMONG CREWMEMBERS AFFECTS THE GROUP'S ABILITY TO ACT IN A COHESIVE MANNER
- A DECLINE IN GROUP COHESION MAY POSE A SAFETY HAZARD FOR CRITICAL TASKS WHICH REQUIRE A COORDINATED CREW EFFORT

RECOMMENDATIONS FOR MONITORING

- MONITOR
  - RESPONSES TO GENERIC CREW DEBRIEF SOFTWARE ONBOARD
  - RESPONSES TO STRUCTURED INTERVIEWS WITH GROUND PERSONNEL
  - REAL-TIME AUDIO CONTENT ANALYSIS
  - REPORTS OF CONFLICTS FROM CREW AND GROUND

INTERPERSONAL CONFLICT

BIOMEDICAL MONITORING AND COUNTERMEASURES

Presenter:	Date:
GERALD TAYLOR / JSC	DEC. 21, 1989

- **HYPOTHESIZED RESULTS AND SIGNIFICANCE**
  - CONFLICT AND DECREASED CREW COHESIVENESS WILL OCCUR MORE FREQUENTLY MID-MISSION
  - MISCOMMUNICATION WILL OCCUR ACROSS CULTURES
  - MORE CONFLICTS WILL OCCUR RELATED TO ROUTINE STATION MAINTENANCE AND PERSONAL HYGIENE ISSUES THAN TO TECHNICAL ISSUES
  - THE GREATEST AMOUNT OF CONFLICT WILL OCCUR ACROSS INTERFACES OF NATIONALITY AND BETWEEN AIR AND GROUND CREWS
  - INFORMAL NORMS FOR CONFLICT MANAGEMENT WILL ARISE DURING THE MISSION
  - CREW COORDINATION AND PERFORMANCE WILL VARY ACCORDING TO THE EFFECTIVENESS OF CONFLICT MANAGEMENT NORMS

INTERPERSONAL CONFLICT

Presenter: GERALD TAYLOR / JSC

Date: DEC. 21, 1989

ANTICIPATED COUNTERMEASURES

- CONFLICT RESOLUTION AND PROBLEM-SOLVING TRAINING
- ESTABLISHMENT AND UTILIZATION OF A CONFLICT MANAGEMENT PROCESS
- TRAINING IN CROSS-CULTURAL DIFFERENCES
- INTEGRATION OF REGULAR CREW MEETINGS INTO THE CREW ACTIVITIES PLAN
- CREW SELECTION FOR COMPATABILITY
- WHOLE CREW TRAINING FOR A MINIMUM OF ONE YEAR PRIOR TO FLIGHT

INTERPERSONAL CONFLICT

Presenter: GERALD TAYLOR / JSC

Date: DEC. 21, 1989

RELATED OPERATIONALLY IMPORTANT PROBLEMS

- SLEEP DISORDERS
- CHANGES IN MOOD / MOTIVATION
- PSYCHOPHYSIOLOGICAL STRESS

PSYCHOPHYSIOLOGICAL STRESS

Historical Background

Psychophysiological stress is known to accompany spaceflight. Evidence suggests that this stress can increase as a mission lengthens (FASEB - Immunocompetence, 1985, pp. 8-9; Robbins Report, 1988, p. 67). If the stress becomes great enough, it can result in a variety of disorders. Among these are increased anxiety, irritability, depression, hostility, immunosuppression, reduced attention, disturbed sleep, disruptions of operational memory, and lowered motivation (Robbins Report, 1988, p. 67; Dantzer and Kelley, 1989, p. 1; Bluth and Helppie, 1986, p. IV-5). Stress is also known to influence decision making (Goldberg Report, 1987, p. 174). Any of these manifestations could have an impact on mission operations.

Both U.S. and Soviet space crews have exhibited hormonal characteristics of psychophysiological stress (Huntoon, et al., 1989, pp. 231-232). Anecdotal and informal reports provide subjective information that suggests that other symptoms of psychophysiological stress are also associated with spaceflight. While in many cases the stress response is adaptive (e.g. in responses to emergencies), prolonged stress appears to be problematic. On one Soviet MIR mission a crewmember experienced cardiac dysrhythmias which were attributed to stress (Bogomolov et al., 1988, p. 26). This problem resulted in the individual's early return to Earth. Another cosmonaut on a long duration mission experienced a stress-induced dermatological disorder.when his fellow crewmember became ill (Lebedev, 1988, p. 336). Because of the necessary interdependence of crewmembers with regard to their mutual safety, the illness of a fellow crewmember could be a significant stressor.

One of the Scientific objectives identified by the Goldberg committee was the development of a means to monitor and mitigate stressful situations on board the space station (Goldberg Report, 1987, p. 177). The FASEB report on human behavior noted the stressors which are likely to be present on board the space station and suggested the training of crewmembers on means for coping with those stressors (FASEB - Human Behavior, 1985, p. 49).

Recommendations for Monitoring

Hormonal indicators of stress (e.g. cortisol levels) would provide objective physiological data regarding stress levels experienced by crewmembers. It would also be of benefit to gain subjective measures of perceived stress. This information could be gathered via an on board computerized crew debrief. Subjective readiness assessments conducted jointly by the crewmember and a member of the Psychosocial Support Team could be conducted prior to critical work (e.g. EVA). This would serve to assess the individual's readiness to take on the additional stress of that work.

Anticipated Countermeasures

A crewmember's ability to realistically assess and regulate their stress level may prove to be one of the most effective countermeasures for psychophysiological stress. Training on how to make such self-assessments would be an important part of preflight training. Regulation of those identified stressors necessitates, however, that crewmembers have a greater degree of autonomy than has been common on previous U.S. space missions. Greater self-control over one's work/rest schedules and access to Psychosocial Support Team members to discuss means for coping with other stressors could greatly enhance the individual's ability to cope with stress. A training module which would seek to prepare the crewmembers for the stresses they may expect to encounter would also be of great benefit. Task rotation is another strategy which may prove beneficial on board space station. Sharing responsibility for critical tasks may be one way to prevent an overload of stress on any one crewmember. Finally, it is likely that a Psychosocial and Practical Support Team for families would facilitate an easier transition of the crewmember both inflight and postflight. Such a team would provide means for compensating the crewmember's family for the extraction of one of its members. The crewmember would not be as likely to experience stress inflight over the well-being of his/her family, and it would ease the transition of the crewmember once he/she is returned to Earth.

Related Operationally Important Problems

Sleep Disorders
Infection
Changes In Mood/Motivation
Impaired Cognition
Interpersonal Conflict

Bluth J and Helppie M. *Soviet Space Stations as Analogs*. Washington, D.C.: NASA; NASA Grant NAGW-659, 1986.

Bogomolov V, Popova I, Egorov A and Kozlovskaya I. The Results of Medical Research During the 326-Day Flight of the Second Principal Expedition on the Orbital Complex "MIR". Gazenko O, editor. *The Second US/USSR Joint Working Group Conference on Space Biology and Medicine*. Moscow: Institute of Medico-Biological Problems of the USSR Ministry of Health; 1988.

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Huntoon C, Johnson P and Cintron N. "Hematology, immunology, endocrinology, and biochemistry." Nicogossian A, Huntoon C, and Pool S, editors. *Space, Physiology, and Medicine*. Philadelphia: Lea and Febiger; 1989:222-239.

Lebedev V. *Diary of a Cosmonaut: 211 Days in Space*. College Station: G.L.O.S.S. Company; 1988.

Robbins F, et al. *Exploring the Living Universe/A Strategy for Space Life Sciences*. Washington, D.C.: NASA; 1988.

HISTORICAL BACKGROUND

- ONE COSMONAUT ON A 326-DAY MIR MISSION EXPERIENCED CARDIAC DYSRHYTHMIAS WHICH WERE ATTRIBUTED TO NEUROEMOTIONAL TENSION. THIS RESULTED IN HIS BEING REPLACED AFTER 175 DAYS ON ORBIT
- ATTENTION AND OPERATIONAL MEMORY HAVE BEEN SHOWN TO BE AFFECTED BY STRESS IN GROUND BASED STUDIES
- SPACEFLIGHT IS ACCOMPANIED BY CLEAR SIGNS OF EMOTIONAL STRESS
- ONE COSMONAUT EXPERIENCED STRESS - INDUCED DERMATOLOGICAL DISORDERS (BLEMISHES AND SKIN PEELING OFF OF HIS BACK) AFTER ONE OF HIS FELLOW CREWMEMBERS HAD BECOME ILL
- INCREASES IN URINARY CORTISOL (AS COMPARED TO PREFLIGHT LEVELS) WERE OBSERVED THROUGHOUT THE SKYLAB FLIGHTS

PSYCHO - PHYSIOLOGICAL STRESS

Presenter: GERALD TAYLOR / JSC

Date: DEC. 21, 1989

SIGNIFICANCE

- PSYCHOPHYSIOLOGICAL STRESS CAN LEAD TO BOTH PHYSICAL AND PSYCHOLOGICAL ILLNESS

RECOMMENDATIONS FOR MONITORING

- MONITOR
  - RESPONSES TO ONBOARD CREW DEBRIEF FOR STRESS ASSESSMENT AND SOURCE DETERMINATION
  - SERUM OR URINARY CORTISOL
  - CRITICAL READINESS (PRIOR TO CRITICAL WORK e.g., EVA)

PSYCHO - PHYSIOLOGICAL STRESS	BIOMEDICAL MONITORIN[G] AND COUNTERMEASURES	
	Presenter: GERALD TAYLOR / JSC	Date: DEC. 21, 1989

- **HYPOTHESIZED RESULTS AND SIGNIFICANCE**
  - SUBJECTIVE REPORTS OF STRESS WILL INCREASE FROM BASELINE PRIOR TO PERFORMANCE OF CRITICAL TASKS
  - HORMONAL INDICATORS OF STRESS WILL SHOW A GENERAL TREND TOWARD INCREASED STRESS AS A FUNCTION OF FLIGHT DURATION

ANTICIPATED COUNTERMEASURES

- FORMAL PSYCHOLOGICAL SUPPORT PROGRAMS FOR CREW AND FAMILY
- TRAINING TO PREPARE FOR LIFE IN AN ISOLATED AND CONFINED ENVIRONMENT
- INCREASE CREW CONTROL OVER WORK / REST SCHEDULING
- SELF - AWARENESS AND SELF - REGULATION ON THE PART OF CREWMEMBERS
- TASK ROTATION AMONG CREWMEMBERS

RELATED OPERATIONALLY IMPORTANT PROBLEMS

- SLEEP DISORDERS
- INFECTION
- CHANGES IN MOOD / MOTIVATION
- IMPAIRED COGNITION
- INTERPERSONAL CONFLICT

NORMAL BODILY STATE

ANEMIA

Historical Background

Anemia is defined as the reduction below normal in the oxygen-carrying capacity in a certain volume of blood due to a decrease in the number of erythrocytes per cubic millimeter, in hemoglobin per 100 milliliters, and in the volume of packed erythrocytes per 100 milliliters of blood. Generally, 12 grams/100 milliliters of hemoglobin is accepted as the lower limit of normal and values below it constitute anemia (Davidson and Henry, 1969, p. 207). The clinical symptoms of anemia are weakness, labored breathing, and excessive heart rate which can be expected to adversely affect the operational performance of the flightcrew. Based on this definition, it has been difficult to document clinical cases of anemia in the crew of any of the spaceflight missions for either the U.S. or the Soviet space programs. However, the consistent reduction in erythrocyte mass, reticulocyte count, and hemoglobin concentrations postflight cannot be disputed (Kimzey et al., 1975, pp. 197-226; Johnson et al., 1977, p. 240; Yegorov, 1981, p. 148; Johnson, 1983, p. 289; Bogomolov et al., 1988, p. 73; Leach et al., 1988; Huntoon et al., 1989, pp. 222, 224). This trend is alarming and steps to monitor these hematologic parameters throughout long duration space travel must be developed (Goldberg Report, 1987, pp. 150-153; Robbins Report, 1988, pp. 46-50; FASEB - Loss of Red Blood Cell Mass, 1985, pp. 5-11, 31-36).

In an effort to determine the cause of the erythrocyte mass loss, the destruction of erythrocytes, decrease in erythrocyte survival, and ineffective erythropoiesis have been studied during spaceflight, but the evidence is inconclusive (Kimzey et al., 1975, pp. 197-226; Johnson et al., 1988, pp. 387-396; Leach and Johnson, 1984, pp. 216-218). Indications are that the number of reticulocytes are reduced postflight and thus erythropoiesis is suppressed. However, the Soviet reports suggest that the number of reticulocytes, 1-3 weeks after long duration flights, is several times higher than the preflight level (Yegorov, 1981, p. 148; Kalandarova, 1986, pp. 8-23). This late response by the bone marrow may be the result of the decrease in erythrocyte mass and erythropoiesis inflight or immediately postflight. The Soviets interpreted the data as a re-adaptation response of the bone marrow to gravity postflight. Further studies must be conducted to clarify these discrepancies.

Erythropoietin is produced by the kidney in response to low oxygen levels in the tissues and stimulates erythropoiesis in the bone marrow (Davidson and Henry, 1969, p. 208). A significant positive correlation between erythropoietin and reticulocyte number was demonstrated in a Spacelab 1 experiment, indicating that production of erythrocytes was associated with erythropoietin level. (Leach et al., 1988, pp. 161-166). The role of erythropoietin in regulating the erythrocyte mass during spaceflight is still unknown and requires further investigation.

Serum erythropoietin levels appear to be decreased (statistically not significant) postflight in the few case studies of the U.S. missions of short duration (Leach and Johnson, 1984, pp. 216-218). The Soviets have reported contrasting results. In most cosmonauts who have flown for more than 2 months, serum erythropoietin levels were lower than those who had spent a shorter time in space, up to 1 month (Kalandarova, 1986, p. 14). However, the erythropoietin values were increased from preflight values for both groups. This issue requires further clarification by preflight, inflight, and postflight monitoring of serum erythropoietin levels.

Although the number of cases are limited, the loss of erythrocyte mass appears to stabilize in long duration flights of 84 days or greater suggesting an adaptation to the weightless environment (Kimzey et al., 1977, pp. 237, 266; Huntoon et al., 1983, p. 223; Bogomolov et al., 1988, p. 73; Yegorov, 1981, p. 145; Goldberg Report, 1987, p. 150). Unfortunately, the available inflight data to support this hypothesis is inadequate and further studies must be conducted.

The significance of these findings was summarized by the Goldberg Report as follows: "As far as is known, the loss of erythrocyte mass is an appropriate adaptation to the cardiovascular changes that occur during spaceflight. At the same time, it is important to evaluate the clinical implications of the anemia should a serious illness or accident occur, especially during long-duration missions." (Goldberg Report, 1987, p. 155). Thus, a high risk of clinical anemia may exist after blood loss injury and menstruation in long duration flights.

Recommendations for Monitoring

The following recommendations were advanced by the Goldberg Report (1987, p. 154), Robbins Report (1988, p. 49), and the *ad hoc* Working Group (FASEB - Loss of Red Blood Cell Mass, 1985, pp. 34-35). More detailed studies on the time course and magnitude of the erythrocyte loss in long duration flights were highly recommended; the parameters of hemoglobin, adjusted hematocrit, and erythrocyte mass should be monitored. Erythrocyte mass should be estimated from blood samples drawn at least twice daily during the first two weeks of the mission and twice weekly thereafter.

In order to identify abnormal bone marrow function in response to blood loss, the reticulocyte counts and age distribution and serum erythropoietin levels must be determined. Because there is a need for improved methods of counting reticulocytes quickly and accurately, the development of a flow cytometer and automated differential counting device for this purpose was recommended. Because of the variability of erythropoietin levels in serum, it may be necessary to examine multiple samples, preflight, at the time of launch and initially every few hours inflight, or possibly more frequently, and postflight.

In order to determine a possible cause for the erythrocyte loss, the destruction of erythrocytes should be monitored by measuring the serum bilirubin level that is indicative of increased hemoglobin metabolism due to erythrocyte lysis. Also, erythrocyte survival should be measured preflight, daily during the first week of flight, weekly thereafter, and postflight. Increase iron turnover in the blood would also indicate erythrocyte destruction and, therefore, should be monitored preflight, inflight, and postflight.

Anticipated Countermeasures

In order to stimulate erythropoiesis in the bone marrow and prevent the development of clinical anemia, an erythropoietin or granulocyte-macrophage colony stimulating factor is administered to the crewmember. In cases of clinical anemia, a transfusion of packed erythrocytes is administered in order to increase erythrocyte mass. In order to prevent the development of severe anemia, it may be necessary to return the crewmember to earth.

Related Operationally Important Problems

Infection
Osteoporosis and Fractures
Increased Muscular Fatigue/Decreased Muscular Strength
Decreased Ability to Emergency Egress
Decreased Ability to Perform Long Duration Tasks

Bogomolov V, Popova I, Egorov A and Kozlovskaya I. The Results of Medical Research During the 326-Day Flight of the Second Principal Expedition on the Orbital Complex "MIR". Gazenko O, editor. *The Second US/USSR Joint Working Group Conference on Space Biology and Medicine.* Moscow: Institute of Medico-Biological Problems of the USSR Ministry of Health; 1988.

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ANEMIA

Presenter: GERALD TAYLOR / JSC

Date: DEC. 21, 1989

HISTORICAL BACKGROUND

- A CONSISTENT DECREASE IN ERYTHROCYTE MASS (U.S.) AND HEMOGLOBIN (SOVIET) FOR SHORT DURATION FLIGHTS
- DECREASE IN SERUM ERYTHROPOIETIN (STIMULATES BONE MARROW TO PRODUCE ERYTHROCYTES) AND RETICULOCYTE COUNT FOR SHORT DURATION FLIGHTS (U.S.)
- IN LONG DURATION FLIGHTS, THE LOSS OF ERYTHROCYTE MASS APPEARS TO STABILIZE AT THE LEVEL OF SHORT FLIGHTS (U.S. AND SOVIET)
- EVIDENCE IS INSUFFICIENT TO IDENTIFY THE CAUSE, SUCH AS, A DECREASE IN ERYTHROCYTE SURVIVAL OR INEFFECTIVE ERYTHROPOIESIS

ANEMIA

Presenter:
GERALD TAYLOR / JSC

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SIGNIFICANCE

- HIGH RISK OF CLINICAL ANEMIA RESULTING FROM BLOOD LOSS INJURY AND AFTER MENSTRUATION DURING LONG DURATION FLIGHTS
- EVIDENCE INSUFFICIENT TO DETERMINE THE RISK OF CLINICAL ANEMIA DUE TO CONTINUED LOSS OF ERYTHROCYTES DURING LONG DURATION FLIGHTS
- THE CLINICAL SYMPTOMS OF ANEMIA ARE WEAKNESS, LABORED BREATHING, AND EXCESSIVE HEART RATE WHICH CAN BE EXPECTED TO ADVERSELY EFFECT THE OPERATIONAL PERFORMANCE OF THE FLIGHT CREW.

ANEMIA

BIOMEDICAL MONITORING AND COUNTERMEASURES

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RECOMMENDATIONS FOR MONITORING

- MONITOR
  - THE TIME COURSE AND MAGNITUDE OF THE ERYTHROCYTE LOSS IN LONG DURATION FLIGHTS
    - HEMOGLOBIN
    - ADJUSTED HEMATOCRIT
    - ERYTHROCYTE MASS
    - RETICULOCYTE COUNTS AND AGE DISTRIBUTION
    - SERUM ERYTHROPOIETIN LEVELS
    - IRON TURNOVER IN THE BLOOD
    - SERUM BILIRUBIN
    - ERYTHROCYTE SURVIVAL

ANEMIA

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- **HYPOTHESIZED RESULTS AND SIGNIFICANCE**

  - DECREASED SERUM HEMOGLOBIN LEVELS, ADJUSTED HEMATOCRIT, AND ERYTHROCYTE MASS ARE INDICATIVE OF ERYTHROCYTE LOSS AND INCREASES THE RISK FOR ANEMIA
  - DECREASED RETICULOCYTE COUNTS AND THEIR ALTERED AGE DISTRIBUTION DEMONSTRATE SUPPRESSED BONE MARROW ERYTHROPOIESIS
  - DECREASED ERYTHROPOIETIN LEVELS IN BLOOD ARE INDICATIVE OF ABNORMAL REGULATION OF ERYTHROPOIESIS IN RESPONSE TO ERYTHROCYTE LOSS
  - INCREASED IRON TURNOVER IN THE BLOOD AND DECREASED ERYTHROCYTE SURVIVAL DEMONSTRATE ERYTHROCYTE LYSIS
  - INCREASED SERUM BILIRUBIN LEVELS IN THE BLOOD ARE INDICATIVE OF INCREASED HEMOGLOBIN METABOLISM DUE TO ERYTHROCYTE LYSIS

ANTICIPATED COUNTERMEASURES

- ADMINISTRATION OF ERYTHROPOIETIN OR GRANULOCYTE - MACROPHAGE COLONY STIMULATING FACTOR TO STIMULATE ERYTHROPOIESIS IN THE BONE MARROW AND PREVENT THE DEVELOPMENT OF CLINICAL ANEMIA
- TRANSFUSION OF PACKED BLOOD CELLS TO INCREASE ERYTHROCYTE MASS IN CASES OF CLINICAL ANEMIA
- RETURN TO EARTH IN ORDER TO PREVENT THE DEVELOPMENT OF SEVERE ANEMIA

ANEMIA

Presenter:
GERALD TAYLOR / JSC

Date:
DEC. 21, 1989

RELATED OPERATIONALLY IMPORTANT PROBLEMS

- INFECTION
- OSTEOPOROSIS AND FRACTURES
- INCREASED MUSCULAR FATIGUE / DECREASED MUSCULAR STRENGTH
- DECREASED ABILITY TO EMERGENCY EGRESS
- DECREASED ABILITY TO PERFORM LONG DURATION TASKS

INFECTION

Historical Background

Infections

Throughout the U.S. space program, the prevention of infectious diseases inflight and postflight have been of major concern. Despite these efforts, inflight and postflight infections of varied etiology have been documented. The greatest number of infections were reported during the early Apollo missions. These infections were classified as upper respiratory infections, gastroenteritis, inguinal rash, contact dermatitis, stomatitis, rhinitis, laryngitis, seborrhea, and skin infections. They were most likely caused by preflight exposure to the infectious agent or spacecraft environmental irritants (FASEB - Immunocompetence, 1985, p. 7; Pierson, 1986, pp. 1-1 through 4-16; Nicogossian and Garshnek, 1989, pp. 17-29).

After a preflight isolation period was instituted for all of the subsequent crews, fewer problems related to infectious diseases were noted but not completely eliminated, even for short duration missions. Contact dermatitis and upper respiratory inflammation were attributed to spacecraft materials, while a urinary tract infection was associated with the urine collecting device (Nicogossian and Garshnek, 1989, p. 20). In a later American mission, 61C, a member of the crew exhibited pharyngitis during the flight. In one instance, a mission was postponed due to an upper respiratory infection of members of the crew (Apollo), but for the remaining cases the impact of the infections on the crew was not evaluated or noted.

Although the Soviets have failed to report any real problems related to infectious diseases in their long duration missions (Yegorov, 1981; Zaloguyev et al. 1985, pp. 64-66; Kalandarova, 1986, pp. 8-23; Bogomolov et al., 1988, p. 26), an eyelid infection (sty) and an incipient axillary furuncle (skin infection) were observed during the 59 day Skylab 3 mission (Taylor et al., 1977, pp. 53-63). Mild dermatitis and a brief episode of unilateral serous otitis (ear infection) were also reported for other Skylab missions (FASEB - Immunocompetence, 1985, p. 6). The indications are that in planning for long duration spaceflight on the Space Station Freedom, two factors exist that pose added risk of infection and must be investigated (FASEB - Immunocompetence, 1985, pp. 3-7, 9-13, 17-25; Robbins Report, 1988, pp. 47, 50). These factors are (1) an attenuated cell-mediated immune response, and (2) physiologic and psychologic responses to "stress".

Attenuated Cell-Mediated Immune Response

The evidence which supports an attenuation of the cell-mediated immune system is consistent for the U.S. Shuttle Transport System missions and Soviet long duration space missions (Taylor et al., 1981, pp. 51-52; Taylor and Dardano, 1983, pp. S55-S59; FASEB - Immunocompetence, 1985, pp 3-6; Meehan, 1987, pp. 225:273-286; Bogomolov et al., 1988, pp. 26; Konstantinova, 1988, pp. 73-104). The impact of this suppression on the development of infections, cancer induction, and crew performance levels has not been described or documented. It is expected that, for long duration missions, an attenuated cell-mediated immune system increases the risk of intracellular bacterial, viral and fungal infections by commensal or latent microbes (Hood et al., 1984, p. 441; Hong, 1986, p. 702). Clinical symptoms of these infections can include vomiting, fever, discomfort, and breathing difficulties which can be expected to adversely affect the operational performance of the crew.

The elements of the immune system which have been impaired postflight are (1) the distribution and counts of specific populations of leukocytes, (2) mitogenic (blastogenic) response of lymphocytes, (3) natural killer cytotoxicity, and (4) cytokine production (alpha-interferon and interleukin 2), (Taylor et al., 1981, pp. 51-52; Taylor and Dardano, 1983, pp. S55-S59; FASEB - Immunocompetence, 1985, pp 3-6; Meehan, 1987, pp. 273-286; Bogomolov et al., 1988, pp. 26; Konstantinova 1988, pp. 73-104). Changes in the leukocyte populations were neutrophilia, monocytopenia, lymphopenia, eosinopenia, reduced numbers of T-lymphocytes (helper), B-lymphocytes, and natural killer cells (FASEB - Immunocompetence, 1985, pp. 3-6). All these immune parameters can easily be monitored during long duration spaceflights. The risk to crewmembers can be minimized by monitoring the level of immunocompetence during flight and, if necessary, administer pre-determined countermeasures to maintain normal immune functions.

Physiologic and Psychologic Responses to Stress

Spaceflight imposes numerous physiological, psychological, and environmental stressors upon the individual (Yegorov, 1981, pp. 12-14; Davydova et al., 1984, pp. 977-989; Kanas, 1985, pp. 806-811; FASEB - Immunocompetence, 1985, pp. 18, 23; Bogomolov, 1988, pp. 26, 58; Konstantinova, 1988, pp. 38-39; Huntoon et al., 1989, pp. 231-232) that may have a profound effect on the immune status of the crewmembers (Taylor and Dardano, 1983, pp. S55-S59; Meehan, 1987, pp. 273-286). Because of the great variability between persons in their response to a particular stressor, this association between stress and reduced immunity during spaceflight has been difficult to document.

However, clinical, epidemiological, psychological, and pathophysiological evidence points toward neural-immune interactions as a pivotal axis through which the external environment can have a profound impact on the individual's state of health (Riley, 1981, pp. 1100-1109; Dorian and Garfinkel, 1987, pp. 393-407; Glaser R et al., 1987, pp. 7-20). A wide range of research in laboratory animals has shown that the nervous system can influence the immune system (Dantzer and Kelley, 1989, pp. 1995-2008). It has been demonstrated that a broad array of stressors can alter the immune response and consequently potentiate the susceptibility to infectious agents such as herpes virus (Rasmussen et al., 1956, pp. 181-187; Jenson and Rasmussen, 1963, pp. 21-23; Dantzer and Kelley, 1989, 1995-2008). Specifically, a decrease in cell-mediated immunity has been reported in response to stress (Locke et al., 1984, pp. 441-453; Stein et al., 1985, pp 827s-833s; Glaser et al., 1986, pp. 675-678; Meehan, 1987, pp. 273-286; Dantzer and Kelley, 1989, pp. 1995-2008). Therefore, reducing the number of known stressors or modulating an individuals response to a particular one (for more details, read the related operationally important problem, Psychophysiological Stress), is an important aspect of maintaining optimum immune functions.

Recommendations for Monitoring

The number of infections such as upper respiratory, skin, and gastrointestinal is monitored by the Environmental Health Facility on Space Station Freedom and the data is forwarded to BMAC and HMF. It is hypothesized that during long duration flights an increased incidence of infections will be observed and prophylaxis in the form of antibiotics and oral flora replacement therapy will be necessary. In order to diagnose any problems related to infectious diseases and the development of a depressed immunity, the distribution and absolute counts of granulocytes, monocytes and subsets of lymphocytes will be monitored (Robbins Report, 1988, p. 50).

The following recommendations were submitted by the *ad hoc* Working Group (FASEB, Immunocompetence, 1985, pp. 29-30) which should provide firm conclusions on the effects of spaceflight on the immunocompetence of the crews that may pose serious health problems. (1) Determine inflight immune response of space crewmembers including antibody production and delayed-type hypersensitivity reactions to common antigens. (2) Study the capacity of T-lymphocytes to respond to mitogens and specific antigens by cytokine production postflight. The cytokines, interleukin-2, interleukin-3, and gamma interferon were suggested. (3) Evaluate the phagocytic and migratory functions of neutrophils and monocytes. (4) Determine the temporal patterns of changes in immune parameters such as white blood cell count, differential count, and mitogenic responsiveness of T-lymphocytes. The sampling times include preflight, inflight at 24-

48 hours, mid-mission, and shortly before reentry; postflight at 24-48 hours, as well as 7, 14, 21, and 30 days.

The highest priority for pre-space station research was to assess the immunocompetence of astronauts during spaceflight. This recommendation was developed by a committee that evaluated the Space Station Infectious Disease Risks (Pierson, 1986, p. A-4). According to report, the emphasis should be placed on specific and non-specific defense mechanisms including phagocytic functions, intestinal motility, and muco-ciliary clearance of the respiratory passages. In order to determine the activation of latent viruses due to spaceflight, it was suggested that a relatively easy prospective clinical study could be implemented which would monitor the shedding of herpes simplex virus and cytomegalovirus before, during, and after shuttle flights. Possible parallel immunological studies could monitor the rise in antibody titers specifically directed against herpes simplex virus or cytomegalovirus and natural killer cytotoxic activity against herpes-infected target cells.

The Robbins Report reiterated that the functional changes in immunology and susceptibility to infectious diseases should be correlated with any qualitative or quantitative changes in hematopoietic cell lines (Robbins Report, 1988, p. 50). This emphasizes the importance of determining the relationship between immunocompetence and susceptibility to infectious diseases in spaceflight. It is clear that, based on the concern expressed by these committees, NASA must develop a strong research program which will answer the critical questions related to the immunocompetence of astronauts during spaceflight of long duration.

Studies which enable NASA to better understand the inter-related mechanisms of stress, immunity, and susceptibility to infectious diseases are crucial in planning for long duration space travel (Robbins Report, p. 67; Goldberg Report, 1987, p. 174; Taylor and Dardano, 1983, pp. S55-S59; Meehan, 1987, pp. 273-286). "Neuroendocrine modulation of human T-cell function following stressful events (including spaceflights) could be investigated by using lymphocyte activation strategies which have been useful in elucidating mechanisms of altered immune regulation in diseases. Since the CNS and immune system interact as a regulatory circuit complete with feedback mechanisms and share common peptide hormones and receptors, future studies may need to focus on the role of endogenous brain peptides and other hormones in modulating human T cell function following exposure to various stressful events." (Meehan, 1987, pp. 273-286)

Anticipated Countermeasures

The anticipated countermeasure for the prevention of infectious diseases is to administer antibiotics and normal flora replacement therapy. In order to enhance immune functions the cytokines, interferon or interleukin, are administered, and in order to minimize stress the countermeasures for psychological stress are invoked.

Related Operationally Important Problems

Anemia
Cancer Induction
Decreased Ability To Perform High Precision Tasks
Decreased Ability to Emergency Egress
Psychophysiological Stress

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INFECTION

BIOMEDICAL MONITORING AND COUNTERMEASURES

Presenter: GERALD TAYLOR / JSC

Date: DEC. 21, 1989

HISTORICAL BACKGROUND

- INFECTIONS
  - THE GREATEST NUMBER OF INFECTIONS SUCH AS UPPER RESPIRATORY INFECTIONS, GASTROENTERITIS, AND SKIN INFECTIONS WERE REPORTED DURING THE EARLY APOLLO MISSIONS
  - AFTER A PREFLIGHT ISOLATION PERIOD WAS INSTITUTED, THE NUMBER OF CASES OF INFECTIOUS DISEASES WERE DRAMATICALLY REDUCED BUT NOT COMPLETELY ELIMINATED
  - CASES OF AN EYE INFECTION (STY), SKIN INFECTION, CONTACT DERMATITIS, UPPER RESPIRATORY INFLAMMATION, URINARY TRACT INFECTION, AND PHARYNGITIS WERE REPORTED SINCE THE LATE APOLLO MISSIONS

Presenter: GERALD TAYLOR / JSC

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INFECTION

- **REDUCED CELL - MEDIATED IMMUNITY MAY INCREASE RISK OF INFECTIONS**
  - CONSISTENT REDUCTION IN LYMPHOCYTE MITOGENIC RESPONSE IN U.S. SHUTTLE MISSIONS POSTFLIGHT
  - DECREASE IN LYMPHOCYTE MITOGENIC RESPONSE FOR LONG DURATION SOVIET MISSIONS
  - DECREASE IN T-LYMPHOCYTE COUNT FOR LONG DURATION SOVIET MISSIONS
  - DECREASE IN NATURAL KILLER CYTOTOXIC ACTIVITY INTERLEUKIN 2, AND INTERFERON FOR LONG DURATION SOVIET MISSIONS

INFECTION

BIOMEDICAL MONITORING AND COUNTERMEASURES

Presenter:	Date:
GERALD TAYLOR / JSC	DEC. 21, 1989

- **STRESS FACTORS REDUCE IMMUNITY AND INCREASE SUSCEPTIBILITY TO INFECTIONS**
  - A NUMBER OF STRESSORS (PSYCHOSOCIAL, PHYSIOLOGICAL, AND ENVIRONMENTAL) HAVE BEEN IDENTIFIED DURING SPACEFLIGHT THAT MAY ADVERSELY AFFECT CELL-MEDIATED IMMUNE RESPONSES AND SUSCEPTIBILITY TO INFECTIONS
  - THE DEGREE OF STRESS APPEARS TO RELATE DIRECTLY TO THE LOSS OF MITOGENIC RESPONSE DURING SPACEFLIGHT
  - OTHER GROUNDBASED STRESSORS, SUCH AS, EXAMINATIONS FOR MEDICAL STUDENTS, WERE ACCOMPANIED BY DECREASED MITOGENIC RESPONSE, REDUCED NATURAL KILLER CYTOTOXIC ACTIVITY, AND LOWERED PRODUCTION OF INTERFERON - GAMMA

INFECTION

Presenter: GERALD TAYLOR / JSC

Date: DEC. 21, 1989

- **STRESS FACTORS REDUCE IMMUNITY AND INCREASE SUSCEPTIBILITY TO INFECTIONS - Continued**
  - STRESSED ANIMALS WERE MORE SUSCEPTIBLE TO INFECTIONS SUCH AS HERPES VIRUS
  - IMPROVED METHODS FOR EVALUATING THE DEGREE OF STRESS EXPERIENCED BY CREWMEMBERS MUST BE DEVELOPED

INFECTION

BIOMEDICAL MONITORING AND COUNTERMEASURES

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Date: DEC. 21, 1989

SIGNIFICANCE

- ATTENUATED CELL-MEDIATED IMMUNE RESPONSE INCREASES THE RISK OF INTRACELLULAR BACTERIAL, VIRAL, AND FUNGAL INFECTIONS DURING LONG DURATION FLIGHTS

- CLINICAL SYMPTOMS OF INFECTIONS CAN INCLUDE VOMITING, FEVER, DISCOMFORT, AND BREATHING DIFFICULTIES WHICH CAN ADVERSELY AFFECT THE OPERATIONAL PERFORMANCE OF THE CREW

RECOMMENDATIONS FOR MONITORING

- MONITOR
  - THE INCIDENCE OF INFECTIOUS DISEASES AND DETERMINATION OF THE CAUSATIVE MICROBE WILL BE RECORDED BY THE ENVIRONMENTAL HEALTH FACILITY AND REPORTED TO BMAC AND HMF
  - A COMPLETE BLOOD COUNT INCLUDING A DIFFERENTIAL LEUKOCYTE COUNT OF MONOCYTES, SUBSETS OF LYMPHOCYTES (B-LYMPHOCYTES, T-LYMPHOCYTES, NK CELLS), AND GRANULOCYTES

- **MONITOR - Continued**
  - CELL - MEDIATED IMMUNE FUNCTIONS
    - * LYMPHOCYTE MITOGENIC RESPONSE
    - * DELAYED - TYPE HYPERSENSITIVITY REACTIONS
    - * NATURAL KILLER CYTOTOXIC ACTIVITY
    - * CYTOKINE PRODUCTION AND ACTIVITY (INTERFERON, INTERLEUKIN 2)
    - * NEUTROPHIL AND MONOCYTE FUNCTIONS
    - * ANTIBODY PRODUCTION TO COMMON ANTIGENS

INFECTION

Presenter:
GERALD TAYLOR / JSC

Date:
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- **HYPOTHESIZED RESULTS AND SIGNIFICANCE**

  - AN INCREASED INCIDENCE OF INFECTIONS WILL NECESSITATE THE USE OF PROPHYLAXIS WITH ANTIBIOTICS AND THE REPLACEMENT OF NORMAL FLORA ORGANISMS SUCH AS LACTOBACILLI
  - THE DEVELOPMENT OF ABNORMAL LEUKOCYTE DIFFERENTIALS AND / OR ABSOLUTE COUNTS ARE INDICATIVE OF INFECTIONS AND / OR SUPPRESSED IMMUNITY DURING SPACEFLIGHT
  - DECREASED CELL - MEDIATED FUNCTIONS ARE INDICATIVE OF SUPPRESSED IMMUNOCOMPETENCE OF THE FLIGHT CREW

ANTICIPATED COUNTERMEASURES

- THE PREFLIGHT HEALTH STABILIZATION PROGRAM
- ADMINISTER PROPHYLAXIS, ANTIBIOTICS AND NORMAL FLORA REPLACEMENT THERAPY, FOR THE PREVENTION OF INFECTIOUS DISEASES
- ENHANCE IMMUNE FUNCTIONS WITH CYTOKINES, INTERFERON AND INTERLEUKIN 2
- MINIMIZE STRESS BY INVOKING THE COUNTERMEASURES FOR PSYCHOPHYSIOLOGICAL STRESS

INFECTION

BIOMEDICAL MONITORING AND COUNTERMEASURES

Presenter: GERALD TAYLOR / JSC

Date: DEC. 21, 1989

RELATED OPERATIONALLY IMPORTANT PROBLEMS

- ANEMIA
- CANCER INDUCTION
- DECREASED ABILITY TO PERFORM HIGH PRECISION TASKS
- DECREASED ABILITY TO EMERGENCY EGRESS
- PSYCHOPHYSIOLOGICAL STRESS

ALTERED PHARMACOLOGIC ACTIVITY

Historical Background

The possibility of altered pharmacologic activity in a microgravity environment is a problem that needs attention. Deviations in the pharmacokinetics of drugs administered to crewmembers during a mission could possibly result in ineffective therapeutic responses or unexpected side effects. These types of reactions could hinder a crewmember's ability to perform effectively. (Nicogossian et al., 1989, p. 235).

Headward fluid shifts resulting in increased central blood volume trigger a series of biochemical and physiological compensatory mechanisms. It is believed that these changes will modify the body's reaction to pharmacologic intervention. Bedrest studies have noted these types of changes in the pharmacodynamics of tested drugs. Scopolamine, an anticholinergic drug used in the treatment of motion sickness, is one of the pharmaceuticals that has been analyzed during bedrest. In the study, it was noted that there were significant differences in the distribution of scopolamine during bedrest when compared to baseline levels. The bioavailability of oral scopolamine under these conditions was determined to be poor and variable. (Putcha, 1989, p. A7)

Recommendations For Monitoring

Altered pharmacologic activity may be detected and/or further prevented in microgravity by monitoring changes from normal, ground-based gastrointestinal and hepatic functions along with changes in the physiologic reactions from commonly used drugs. This will enable us to equate deviations in drug clearance (metabolism and elimination) and allow us to change drug form/dose/interval as well as route to optimum levels for therapeutic response.

In monitoring these parameters, we expect to encounter changes in drug reaction/function. Appropriate countermeasures would then be implemented to counteract these potential problems.

Anticipated Countermeasures

Change and optimize drug form/dose/route/interval and possibly drug choice.

Related Operationally Important Problems

Cardiac Dysrhythmias
Infection
Osteoporosis and Fractures
Renal Stones
Visual Dysfunction

Huntoon C, Johnson P and Cintron N. "Hematology, immunology, endocrinology, and biochemistry." Nicogossian A, Huntoon C, Pool S, editors. *Space Physiology and Medicine.* Philadelphia: Lea and Febiger; 1989:235-236.

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ALTERED PHARMACOLOGIC ACTIVITY

BIOMEDICAL MONITORING AND COUNTERMEASURES

Presenter: GERALD TAYLOR / JSC

Date: DEC. 21, 1989

HISTORICAL BACKGROUND

- HEADWARD FLUID SHIFTS IN MICROGRAVITY TRIGGER A SERIES OF BIOCHEMICAL AND PHYSIOLOGICAL COMPENSATORY MECHANISMS
- BEDREST STUDIES HAVE NOTED SIGNIFICANT CHANGES IN DRUG ACTION ON PREVIOUSLY TESTED PHARMACEUTICALS

SIGNIFICANCE

- CHANGES IN THE PHARMACOKINETICS OF DRUGS ADMINISTERED TO CREWMEMBERS DURING A MISSION COULD POSSIBLY RESULT IN INEFFECTIVE THERAPEUTIC RESPONSE OR UNEXPECTED SIDE EFFECTS

RECOMMENDATIONS FOR MONITORING

- MONITOR
  - DEVIATIONS FROM NORMAL GI AND HEPATIC FUNCTION
  - POTENTIALLY HAZARDOUS DRUG REACTIONS
  - DEVIATIONS IN NORMAL PHARMACOLOGIC REACTIONS FROM COMMONLY USED DRUGS (i.e., PLASMA DRUG LEVELS OVER SPECIFIED TIME PERIODS)
- HYPOTHESIZED RESULTS AND SIGNIFICANCE
  - CHANGES IN GASTRIC AND / OR HEPATIC FUNCTION COUPLED WITH REDUCED EFFICACY OF SPECIFIED, COMMONLY USED PHARMACEUTICALS ARE EXPECTED

ANTICIPATED COUNTERMEASURES

- THROUGH GI AND HEPATIC MONITORING, OPTIMUM DRUG ROUTES WILL BE SELECTED
- THROUGH PLASMA DRUG LEVEL MONITORING, OPTIMUM DRUG FORM / DOSE / INTERVAL AND POSSIBLY DRUG CHOICE WILL BE SELECTED

RELATED OPERATIONALLY IMPORTANT PROBLEMS

- CARDIAC DYSRHYTHMIAS
- INFECTION
- OSTEOPOROSIS AND FRACTURES
- RENAL STONES
- VISUAL DYSFUNCTION

ALTERED CARDIOVASCULAR FUNCTION

Historical Background

During spaceflight, a loss of the gravity dependent blood pooling in the legs that occurs when the body is standing, is experienced. The volume of fluid associated with this pooling is redistributed in the body, and is primarily responsible for the facial edema observed in the participants of space missions. This volume shift is also thought to play a role in space adaptation syndrome (Robbins Report, 1988, pp. 40-43; Levy and Talbot, 1983; Dietlein, 1977, pp. 408-418). The complex alterations in cardiovascular reflexes and endocrine status associated with the lack of normal venous pooling may alter cardiovascular function. The reports of alteration in cardiac function are based on either the small amount of echocardiographic data obtained during Shuttle flights, or on responses to orthostatic stress immediately following space flight. The inflight echocardiographic data demonstrate changes consistent with changes in fluid compartmentalization, but it is unclear if altered myocardial performance (either contractility or heart rate) is altered independent of changes in blood volume (Robbins Report, 1988, pp. 41-42).

Early observations in humans of significant changes in cardiac function were noted during the inflight and immediate postflight periods of a mission (Blomqvist, 1983; Bungo, 1989, pp. 985-990). Standard posterior-anterior chest X-rays were taken before and after each U.S. space flight, and these films have provided a base for determining changes in cardiac silhouette size. Each of the nine Skylab crew members showed moderate decreases in cardiothoracic ratios (Nicogossian, et al., 1976, pp. 362-365; Nicogossian, et al., 1977 pp. 400-405).

Redistribution and reduction of blood volume that effect cardiac function was noted in the Robbins committee report as physiological change that occurs during space flight (Robbins Report, 1988, pp. 18, 40, 48-49). The recommendations of the committee were to increase the number of studies performed both on the ground (bed rest studies, neutral buoyancy, etc.), and inflight to: (1) verify the degree of cardiovascular deconditioning that occurs, and (2) define the role of exercise as a countermeasure to cardiovascular deconditioning. The committee also suggested that instrumentation for onboard hemodynamic monitoring should be implemented according to a well-defined, long-term target.

Cardiovascular adaptation to altered gravitational stimulation was noted in <u>A Strategy for Space Biology and Medical Science</u> as being a significant response that requires further investigation

(Goldberg Report, 1987, p. 137). Perhaps the most interesting observation of the Goldberg committee was that "...In general, the cardiovascular system functions well in spaceflight. On the other hand, the successful adaptation may be viewed as directly responsible for the cardiovascular dysfunction that is apparent upon the return to normal gravity. There is an alternative view- that the normal regulatory mechanisms are unable to deal with the fluid shift that occurs upon entry into microgravity, so that there is a sustained hyperdynamic circulatory state that has the potential of causing myocardial dysfunction even in space (Goldberg Report, 1987, p. 137). " The recommendation that more extensive monitoring of cardiac function during spaceflight may help resolve this issue followed.

The life sciences research office of the Federation of American Societies for Experimental Biology (FASEB) published a committee report regarding research opportunities in cardiovascular deconditioning caused by space flight (Levy and Talbot, 1983). In the report, it is noted that evidence of cardiovascular deconditioning during space flight is evident from data collected by both Soviet and United States scientists (Bogomolov, et al., 1988). The committee concluded that more precise data is needed regarding the nature and mechanisms of cardiovascular adaptations that result from exposure to a space flight environment. Of particular interest are the dimensions and practical significance of possible regressive changes in the myocardium and other parts of the cardiovascular system. The FASEB group also recommended that research investigating the development of effective countermeasures to cardiovascular deconditioning be conducted.

Recommendations for Monitoring

Appropriate monitoring for changes in cardiac function must include methods to elucidate the mechanisms that are responsible for the change in cardiovascular function. These mechanisms include hypovolemia, autonomic dysfunction, altered central cardiac function, altered peripheral vascular control, and loss of skeletal muscle tone of the lower extremities. Measurements of hematocrit, weight, and plasma volume during flight can track hypovolemia. Measurements of heart rate and blood pressure responses to "orthostatic stress" using lower body negative pressure (LBNP) as well as a test of baroreceptor function (using either Valsalva's maneuver, a neck barocuff, a cold pressor test , or isometric exercise) can discern changes in autonomic function. Altered central cardiac function can best be detected by using serial two dimensional echocardiographic measures of cardiac volumes and changes in ascending aortic blood flow velocity using Doppler echocardiography during rest and a cardiovascular stress (LBNP, exercise). Altered cardiac function may also be detected using a bioimpedance technique to detect changes in cardiac output. Changes in peripheral vascular control can be measured utilizing the above techniques and peripheral Doppler blood flow measurements during either a ramp or prolonged LBNP test. Loss of skeletal muscle tone in the legs can be assessed by measuring changes in the volume of the legs and by tests of leg strength.

Anticipated Countermeasures

LBNP inflight, ingestion of saline or other isotonic beverage before landing, LBPP (anti g suits) during landing and egress, appropriately prescribed exercise.

Related Operationally Important Problems

Cardiac Dysrhythmias
Impaired Thermoregulation
Decreased Ability To Emergency Egress

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Equipment For Monitoring Changes in Cardiovascular Function

LBNP (Orthostatic Stressor)
Hematocrit Centrifuge, Capillary tubes, Lancets (Hypovolemia)
Body Mass Measuring Device (Hypovolemia)
Isokinetic Dynamometer (Leg Strength)
Bioimpedance Analyzer (Central Cardiac Function)
Blood Pressure Device (Autonomic function)
Electrocardiograph (Heart rate and rhythm to LBNP and Exercise)
Two dimensional echocardiograph with Doppler velocimeter (Central Cardiac Function)
Peripheral Doppler velocimeter (Peripheral blood flow)
Limb plethsmograph (Hypovolemia, muscle tone, peripheral blood flow)
Neck Barocuff (Autonomic Dysfunction)

ALTERED CARDIOVASCULAR FUNCTION

BIOMEDICAL MONITORIN… AND COUNTERMEASURES

Presenter: GERALD TAYLOR / JSC

Date: DEC. 21, 1989

HISTORICAL BACKGROUND

- STANDARD POSTERIOR - ANTERIOR CHEST X-RAYS TAKEN BEFORE AND AFTER EACH U.S. SPACE FLIGHT HAVE PROVIDED A BASIS FOR DETERMINING CHANGES IN CARDIAC SILHOUETTE SIZE. EACH OF THE NINE SKYLAB CREW MEMBERS SHOWED MODERATE DECREASES IN CARDIOTHORACIC RATIOS

- EVIDENCE OF ALTERATIONS IN CARDIAC FUNCTION DURING SPACE FLIGHT HAS BEEN OBSERVED IN ECHO - CARDIOGRAPHIC AND LBNP DATA COLLECTED BY BOTH SOVIET AND U.S. SCIENTISTS

SIGNIFICANCE

- ALTERATION IN CARDIAC FUNCTION WILL ADVERSELY IMPACT THE ABILITY TO PERFORM EMERGENCY EGRESS (PRIMARILY DUE TO ORTHOSTATIC HYPOTENSION), AND MAY DEGRADE THE ABILITY TO COMPLETE STRENUOUS EVA AND IVA TASKS

RECOMMENDATIONS FOR MONITORING

- MONITOR
  - HEMATOCRIT, BODY MASS, AND PLASMA VOLUME
  - HEART RATE AND BLOOD PRESSURE RESPONSE DURING LBNP
  - BARORECEPTOR FUNCTION
  - CENTRAL CARDIAC FUNCTION (STRUCTURES AND BLOOD FLOW VELOCITIES)
  - CARDIAC OUTPUT
  - PERIPHERAL VASCULAR CONTROL
  - LOSS OF SKELETAL MUSCLE TONE IN THE LEGS

ALTERED CARDIOVASCULAR FUNCTION

BIOMEDICAL MONITORING AND COUNTERMEASURES

Presenter:	Date:
GERALD TAYLOR / JSC	DEC. 21, 1989

- **HYPOTHESIZED RESULTS AND SIGNIFICANCE**
  - DECREASE IN CARDIAC MASS
  - RELATIVE HYPOVOLEMIA
  - ALTERED BARORECEPTOR FUNCTION
  - INCREASED COMPLIANCE OF THE VASCULAR TISSUE
  - NEUROENDOCRINE CHANGES
  - THESE CHANGES WILL RESULT IN THE INDUCEMENT OF ORTHOSTATIC INTOLERANCE UPON RETURN TO GRAVITY, AND MAY ALSO EFFECT THE ABILITY TO PERFORM STRENUOUS CARDIOVASCULAR WORK (DURING EVA AND POSSIBLY EGRESS)

ANTICIPATED COUNTERMEASURES

- APPROPRIATELY PRESCRIBED EXERCISE (PERHAPS DURING LBNP)
- LBNP
- FLUID LOADING (SALINE OR OTHER ISOTONIC BEVERAGE)
- LBPP DURING LANDING AND EGRESS

RELATED OPERATIONALLY IMPORTANT PROBLEMS

- DECREASED ABILITY TO EMERGENCY EGRESS
- CARDIAC DYSRHYTHMIAS
- DECREASED ABILITY TO PERFORM LONG DURATION TASKS
- INCREASED MUSCULAR FATIGUE / DECREASED MUSCULAR STRENGTH

NORMAL RISK LEVELS

RENAL STONES

Historical Background

The possibility of astronauts developing renal stones during long-duration space flights is of major concern. Exposure to microgravity for extended periods of time has been shown to cause demineralization of bones. These minerals are passed to the blood, filtered by the kidneys, and excreted in the urine, increasing the risk of sedimentation, leading to renal stone formation. The severity of the pain associated with renal stones is such that emergency rescue and/or possibly abortion of a mission could result.

Calcium is the mineral of highest concern, for it is the major constituent of nearly all stone forming salts. A considerable rise in urinary calcium has been observed in nearly all space missions. This condition develops soon after space flight begins, reaches a peak, and is sustained at that level throughout the flight. (Cintron, 1987, p. 13). Long duration urinary calcium data were made available through the Skylab program, where it was noted on all three missions that urinary calcium levels increased approximately 80-100 percent above baseline levels, then remained at these levels for the remainder of the flights. (Whedon, 1977, pp. 166-167). Increased urinary calcium levels have also been experienced by the Soviets during the Mir missions.

Urinary phosphate and oxalate levels have been found to also increase in microgravity. These minerals couple with calcium to produce the primary stone forming salts (calcium phosphate and calcium oxalate).

Other factors which may attribute to renal stone formation in microgravity include high levels of exercise, diets high in animal protein, and dehydration. These aid in higher plasma mineral concentrations, potentially contributing to increased saturations of stone forming salts in the urine.

Committees and study groups which were banded to develop strategies for space science for the upcoming years have pointed out that renal stone formation is of concern and needs to be further studied. Both the Goldberg Report and FASEB have stated an interest in the physiological mechanisms by which renal stones are formed in microgravity environments.

Recommendations For Monitoring

Renal stone formation may be detected and/or prevented by monitoring the concentration of stone forming salts (calcium phosphate, calcium oxalate, uric acid, etc.) in the urine. As the concentration of these salts increases, the possibility of renal stone formation increases. Urine volume, osmolality, and pH should also be monitored, for dehydration, increased specific gravity, and increased acidity of the urine are other symptoms of renal stone formation.

In monitoring these parameters, we expect to encounter increased urinary salts, specific gravity and acidity along with decreased urine volume. Appropriate countermeasures would then be implemented to counteract these potential problems.

Anticipated Countermeasures

Administer Fluids, Replacement of Mineral Inhibitors (i.e. Citrate), Lower Calcium and Animal Protein Levels in the Diet, Stimulate ADH Production Through Pharmacologic Means

Related Operationally Important Problems

Osteoporosis and Fractures
Altered Pharmacologic Activity

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RENAL STONES

BIOMEDICAL MONITORING
AND
COUNTERMEASURES

Presenter: GERALD TAYLOR / JSC

Date: DEC. 21, 1989

HISTORICAL BACKGROUND

- RISES IN URINARY CALCIUM, PHOSPHATE, AND OXALATE LEVELS HAVE BEEN OBSERVED IN NEARLY ALL SPACE MISSIONS
- URINARY CALCIUM INCREASED 80-100 PERCENT ABOVE BASELINE LEVEL DURING SKYLAB WITH NO SUGGESTION OF DECLINE
- HIGH LEVELS OF EXERCISE, DIETS HIGH IN ANIMAL PROTEIN, AND DEHYDRATION AID IN INCREASED URINARY SALTS

SIGNIFICANCE

- EXPOSURE TO MICROGRAVITY FOR LONG PERIODS OF TIME WILL INCREASE THE RISK OF RENAL STONE FORMATION.

RENAL STONES

Presenter: GERALD TAYLOR / JSC

Date: DEC. 21, 1989

RECOMMENDATIONS FOR MONITORING

- **MONITOR**
  - CONCENTRATION OF STONE FORMING SALTS IN THE URINE
  - URINE OSMOLALITY, VOLUME, SPECIFIC GRAVITY, AND pH
- **HYPOTHESIZED RESULTS AND SIGNIFICANCE**
  - INCREASED URINARY SALTS, SPECIFIC GRAVITY, AND ACIDITY COUPLED WITH DECREASED URINE VOLUME ARE TRENDS WE EXPECT TO ENCOUNTER.

RENAL STONES

ANTICIPATED COUNTERMEASURES

- ADMINISTER FLUIDS
- REPLACEMENT OF INHIBITORS (i.e., CITRATE)
- LOWER CALCIUM AND ANIMAL PROTEIN LEVELS IN DIET
- STIMULATE ADH PRODUCTION THROUGH PHARMACOLOGIC MEANS

RELATED OPERATIONALLY IMPORTANT PROBLEMS

- OSTEOPOROSIS AND FRACTURES
- ALTERED PHARMACOLOGIC ACTIVITY

CARDIAC DYSRHYTHMIAS

Historical Background

During spaceflight, a loss of the gravity dependent blood pooling in the legs occurs in a one-gravitational environment when the body is standing. The volume of fluid associated with this pooling is redistributed in the body, and is primarily responsible for the facial edema observed in the participants of space missions. This volume shift is also thought to play a role in space adaptation syndrome (Robbins Report, 1988, pp. 40-43; Bungo, 1985, pp. 985-990; Levy and Talbot, 1983; Dietlein, 1977, pp. 408-418). The complex alterations in cardiovascular reflexes and endocrine status associated with the lack of normal venous pooling may alter cardiovascular function and effect normal cardiac rhythm.

Various levels of cardiac dysrhythmias have occurred throughout the U.S. space program (Bungo, 1989, pp. 197-199). During the Gemini, Apollo, and Skylab series of flights the majority of the dysrhythmias noted were either occasional unifocal premature ventricular contractions (PVCs) or minor supraventricular dysrhythmias. One Skylab crewmember had a five beat run of ventricular tachycardia during an LBNP test and during extravehicular activity and lunar surface EVAs, two of the Apollo 15 crew developed cardiac dysrhythmias (FASEB - Cardiovascular Deconditioning, 1984, p. 21). During the Shuttle program, at least two of the crewmembers have developed ventricular ectopy during the reentry phase of the flight; one of these exhibited up to 16 PVCs a minute (Bungo, et al., 1983).

The Robbins committee report notes that a broad range of cardiac dysrhythmias have occurred during space flight, and that a Soviet cosmonaut was rescued after a flight duration of six months because of cardiac dysrhythmias (Robbins Report, 1988, p. 41). This cosmonaut is alluded to in a joint US/USSR conference on Space Biology and Medicine report (Bogomolov, 1988). The dysrhythmia was described as periodic atrial extrasystoles that occurred during exercise training. Subsequent evaluations did not reveal any organic changes in his myocardium and no more extrasystoles were noted during physical training. The recommendations of the Robbins committee were to increase the number of studies performed both on the ground (bed rest studies, neutral buoyancy, etc.), and inflight to: (1) verify the degree of cardiovascular deconditioning that occurs, and (2) define the role of exercise as a countermeasure to cardiovascular deconditioning. The committee also suggested that instrumentation for onboard hemodynamic monitoring should be implemented according to a well-defined, long-term target.

Cardiovascular adaptation to altered gravitational stimulation was noted in A Strategy for Space Biology and Medical Science as being a significant response that requires further investigation (Goldberg Report, 1987, p. 137). Perhaps the most interesting observation of the Goldberg committee was that "...In general, the cardiovascular system functions well in spaceflight. On the other hand, the successful adaptation may be viewed as directly responsible for the cardiovascular dysfunction that is apparent upon the return to normal gravity. There is an alternative view- that the normal regulatory mechanisms are unable to deal with the fluid shift that occurs upon entry into microgravity, so that there is a sustained hyperdynamic circulatory state that has the potential of causing myocardial dysfunction even in space (Goldberg Report, 1987, p. 137). " The recommendation followed that more extensive monitoring of cardiac function, including monitoring of cardiac rhythm, during spaceflight may help resolve this issue.

The life sciences research office of the Federation of American Societies for Experimental Biology (FASEB) published a committee report regarding research opportunities in cardiovascular deconditioning caused by space flight (Levy and Talbot, 1983). In the report it is noted that evidence of "cardiovascular deconditioning" during space flight is present in data collected by both Soviet and United States scientists. The committee concluded that more precise data are needed regarding the nature and mechanisms of cardiovascular adaptations that result from exposure to a space flight environment. The FASEB group also recommended that research investigating the development of effective countermeasures to cardiovascular deconditioning be conducted.

Recommendations for Monitoring

Appropriate monitoring for changes in cardiac rhythm would include inflight measurements of cardiac rhythm during rest, exercise and LBNP, electrolyte imbalance, and measures of autonomic function.

Anticipated Countermeasures

Pharmacologic (beta-blockers, etc.), Nutritional Additives (Supplemental electrolytes), exercise, saline or other isotonic beverage ingestion before reentry, and aggressive pre-flight screening of crew members to detect any type of underlying cardiovascular disease that may precipitate a dysrhythmia.

Related Operationally Important Problems

Increased Muscular Fatigue/Decreased Muscular Strength
Altered Cardiovascular Function
Decreased Ability To Emergency Egress

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Equipment For Monitoring Cardiac Dysrhythmias

LBNP (Orthostatic Stressor)
Blood Pressure Device (Autonomic function)
Electrocardiograph (Heart rate and rhythm to LBNP and Exercise)
Holter Monitor (24 hr cardiac rhythm)
Neck Barocuff (Autonomic Dysfunction)
Ion Chromatograph

HISTORICAL BACKGROUND

- ONE SKYLAB CREWMEMBER HAD A FIVE BEAT RUN OF VENTRICULAR TACHYCARDIA DURING AN LBNP TEST
- DURING EVA AND LUNAR SURFACE EVA, TWO OF THE APOLLO 15 CREW DEVELOPED CARDIAC DYSRHYTHMIAS
- DURING THE SHUTTLE PROGRAM AT LEAST TWO CREWMEMBERS HAVE DEVELOPED VENTRICULAR ECTOPY DURING THE REENTRY PHASE OF FLIGHT, ONE OF THESE EXHIBITED UP TO 16 PVCs A MINUTE
- A SOVIET COSMONAUT WAS RESCUED AFTER A FLIGHT DURATION OF SIX MONTHS BECAUSE OF PERIODIC ATRIAL EXTRASYSTOLES THAT OCCURRED DURING EXERCISE TRAINING. SUBSEQUENT EVALUATIONS DID NOT REVEAL ANY ORGANIC CHANGES IN HIS MYOCARDIUM AND NO MORE EXTRASYSTOLES WERE NOTED

CARDIAC DYSRHYTHMIAS

BIOMEDICAL MONITORING AND COUNTERMEASURES

Presenter: GERALD TAYLOR / JSC

Date: DEC. 21, 1989

SIGNIFICANCE

- DYSRHYTHMIAS, IN PARTICULAR VENTRICULAR ECTOPY OR ATRIAL ECTOPY AT A RAPID RATE, CAN BE INCAPACITATING OR LIFE - THREATENING

RECOMMENDATIONS FOR MONITORING

- MONITOR
  - CARDIAC RHYTHM DURING REST, EXERCISE, AND LBNP
  - SERUM ELECTROLYTES (POTASSIUM IS OF PARTICULAR IMPORTANCE)
  - AUTONOMIC FUNCTION

- **HYPOTHESIZED RESULTS AND SIGNIFICANCE**
  - CARDIAC RHYTHM WILL NOT ALTER DANGEROULSY IN MOST CREWMEMBERS; HOWEVER, CLINICALLY SIGNIFICANT DYSRYTHMIAS WILL OCCUR IN SOME.

ANTICIPATED COUNTERMEASURES

- PHARMACOLOGIC (BETA - BLOCKERS, etc.)
- NUTRITIONAL ADDITIVES (SUPPLEMENTAL ELECTOLYTES)
- FLUID LOADING (SALINE OR OTHER ISOTONIC BEVERAGE)
- APPROPRIATELY PRESCRIBED EXERCISE
- AGRESSIVE PREFLIGHT SCREENING OF CREW TO DETECT UNDERLYING CARDIAC DYSRHYTHMIAS

RELATED OPERATIONALLY IMPORTANT PROBLEMS

- DECREASED ABILITY TO EMERGENCY EGRESS
- ALTERED CARDIOVASCULAR FUNCTION
- DECREASED ABILITY TO PERFORM LONG DURATION TASKS

CANCER INDUCTION

Historical Background

Radiation Exposure

Since the beginning of man's exploration into space, a primary concern has been the protection of both man and animal against possible excessive radiation exposure due to galactic cosmic rays, solar flare particles, and trapped charged particles of the radiation belts (Hekhuis, 1961; p. 57; Lushbaugh, 1974, p. 512; Robbins Report, 1988, p. 55; Goldberg Report, 1987, p. 53). Because of the type of radiation in outer space and its potential hazard to living cells (Rust, 1982, pp. 939-946), radiation exposure safety limits in space must be established based on its biological effects.

"The records of exposures to ionizing radiation to date indicate that inflight dose rates and total doses have been well within the operational safety limits employed by NASA (National Research Council). The crude mean total dose in the ten Apollo missions, each lasting an average of 9.3+ days, was approximately 0.43 rad. In the 85-day Skylab 4 mission, the mean dose was 7.8 rads, and in eight Space shuttle missions, the overall mean total dose was 0.42 rad," (FASEB, Immunocompetence, 1985, p. 21). The total reported dose absorbed by a Soviet cosmonaut in 326 days of flight was 7.6 rads (Bogomolov et al., 1988, p. 16) and the crew irradiation level for the Soviet Salyut 6 mission (175-day) was 3.2-5.8 rads. However, a major solar flare proton shower could result in 1000 rads total body irradiation in an unshielded environment. This is an acute lethal dose (Hekhuis, 1961, p. 57; Lushbaugh, 1974, p. 495).

Although, the radiation exposure to date has not had any adverse affect on the crew's ability to carry out a mission, the estimated crew exposures for the 90-day Space Station mission range is from 15-20 rad. This estimate is below the recommended daily limit of .22 rad for bone marrow, eye lens and skin, but exceeds the limit for testis according to the National Research Council, 1970 (Lushbaugh, 1974, p. 514; FASEB, Immunocompetence, 1985, p. 21). More recently, the exposure limits for 90-day Space Station were estimated at 17.6 rads for skin and 9.9 rads for blood forming organs under Solar Max conditions while higher values of 35.1 rads and 16.2 rads, respectively, were listed under Solar Min conditions (McCormack and Nachtwey, 1989, p. 345). Therefore, it is crucial to monitor the exposure levels and evaluate the effect of the radiation exposure on humans at the genetic level. This is the only way to detect radiation damage that may have the potential of transforming normal cells, to determine increased risk levels for cancer induction in humans living in space, and to establish radiation safety limits that are based on biological effects (Robbins Report, 1988, p. 65).

Spaceflight-Induced Chromosomal Aberrations

Few human studies have been done to determine biological effect of radiation exposure during spaceflight. "The biological effects of radiation on humans are commonly grouped into two categories: acute and long-term. Acute effects include radiation sickness and death; long-term effects are carcinogenesis, teratogenesis, formation of cataracts, and damage to nondividing cells." (Robbins Report, p. 55).

One biological effect of radiation is genetic or chromosomal damage. The earliest attempt to determine the effects of spaceflight on the frequency of chromosomal aberrations were documented during the Gemini and Apollo missions (Kimzey et al., 1975, p. 223). Mitogen-stimulated lymphocytes were arrested at metaphase and the chromosomes were analyzed for abnormalities. Three tentative conclusions were reached: "1. Postflight aberrations are approximately double preflight values, 2. there is a rather constant postflight aberration yield which seems to be dependent on the duration of flight, and 3. Baseline or preflight values in experienced astronauts appear to be higher than in other crewmen" (Kimzey et al., 1975, p. 224).

During the Skylab missions, the above conclusions could not be supported by the data from a similar study, but again only a small number of cells for each specimen were evaluated that were not adequate to form any firm conclusions (Lockhart, 1977, p. 217). Although these limited studies are unable to show any radiation-induced detrimental chromosomal effects, the increased estimated exposure on Space Station leads scientists to expect that space crews may experience reproducible chromosomal changes to spaceflight (Goldberg Report, p. 55-57; Robbins Report, p. 65; FASEB, Immunocompetence, 1985, p. 21).

Carcinogenesis

"One of the major effects of low-level radiation is carcinogenesis" (Robbins Report, p. 63). Carcinogenesis is the process by which a normal cell is converted or transformed into a cancer cell and its progeny form a neoplastic tumor (Hood et al., 1984, p. 496). It has become clear that high linear energy transfer (LET) radiation and high charge and energy (HZE) ionized particles in the space environment, are carcinogenic. Since the relative biological effects of this type of radiation have not been determined, the risk of cancer induction is not clear. (Robbins Report, pp. 55-63; Goldberg Report, pp. 53-55).

The mechanisms of carcinogenesis by physical agents, such as radiation, are still obscure. "Ultraviolet and gamma irradiation are highly mutagenic, acting directly on nucleic acids to cause genetic changes," (Hood et al., 1984, p. 500). The transformation can occur when the cell synthesizes new DNA in a different sequence than the original DNA (mutation). The transformed cell then reproduces and forms a clone of cancer cells (neoplasms). Other neoplastic transformations may arise by the activation of oncogenes that are present in normal cells (Lebowitz, 1983, pp. 657-662; Marx, 1984, pp. 673-676; Santos et al., 1984, pp. 661-664; Hood et al., 1984, p. 506). Activation and expression of these oncogenes may transform the cell as indicated by the production of specific proteins (Hood et al., 1984, p. 509). If radiation exposure, genetic/chromosomal damage, and oncogene activation are monitored during spaceflight, the biological effects of high LET radiation and cancer risk can be established.

Attenuated Natural Killer Cytotoxicity

Natural killer cytotoxic activity is a primary host defense mechanism against tumor development (Hood et al., 1984, p. 515; Romano, 1986, p. 73). As normal cells are transformed, evidence suggests that natural killer cells attack these transformed cells before they are able to form a clone of cancer cells. During the Soviet long duration spaceflights, natural killer cytotoxic activity was markedly reduced postflight (Konstantinova, 1988, p. 29). In addition, the levels of interleukin 2 and interferon, known stimulators of natural killer cytotoxic activity, were also suppressed. It is postulated that the increased radiation exposure of the flightcrew will increase the rate of neoplastic transformation of cells. If the primary host defense mechanism against tumor development is suppressed, one can postulate that the risk of cancer induction is greatly enhanced. It is important to monitor the natural killer cytotoxic function during spaceflight to insure that the host defenses against tumor development is not dangerously altered.

The mechanisms of the suppression of natural killer cytotoxicity are unknown. However, the function is radiation-sensitive (Zarcone, 1989, pp. 1615-1621) and the higher radiation exposure on Space Station may have a detrimental effect. Stress-induced alterations of natural killer cytotoxicity have also been reported (Shavit, 1985, pp. 834s-836s; Blazar et al., 1986, pp. 26-36; Glaser et al., 1986, pp. 675-678; Dantzer and Kelly, 1989, pp. 1995-2008), and animal studies have demonstrated that stress can enhance the development of experimental tumors (Sklar & Anisman, 1979, pp. 513-515; Riley, 1981, pp. 1100-1109: Asterita, 1985, pp. 143, 145: Shavit, 1985, p. 834). However, a clear cause and effect relationship between stress, reduced natural killer cytotoxic activity, and tumor development has not been demonstrated. A number of stressors, psychological, physiological, and environmental, have been identified on spaceflight (Davydova et al., 1984, pp. 977-989; Kanas, 1985, pp. 806-811; Robbins Report, p. 67; Goldberg Report, 1987, p. 174) which may have adverse effects on natural killer cytotoxic function and thereby enhance cancer induction.

Recommendations for Monitoring

The Goldberg Report (1987, pp. 55, 57) recommended that the effects of radiation, especially the high LET radiation from heavy ions and HZE particles, on the frequency of cancer induction or transformations in cell populations be determined. The Robbins Report (1988, pp. 64, 65) reiterated these recommendations and extended the necessary studies to include the low dose/rate effect of high linear energy transfer radiation in cancer induction, cataractogenesis, embryonic development, and the functioning of the nervous system. The Report also promoted as a high priority, the development of improved passive dosimeters and appropriate biological dosimeters that actually provide a method for monitoring the biological effects of radiation.

In order to monitor chromosomal changes in response to spaceflight, cytogenetic studies of human blood lymphocytes stimulated with mitogen and arrested at metaphase should be continued with modern automated instrumentation. Because natural killer cytotoxic activity is radiosensitive, this function may also serve as a biological dosimeter.

In order to monitor the risk of cancer induction in the hemopoietic cells, unscheduled DNA synthesis and increased levels of oncogene products in lymphocytes stimulated with mitogen and arrested at metaphase can be measured. These parameters are indicators of DNA repair and oncogene activation, respectively, and can be used as biological dosimeters during spaceflight.

Anticipated Countermeasures

In order to enhance natural killer cytotoxic function and prevent cancer induction, the cytokines, interferon or interleukin 2, may be administered to the crewmember. To prevent stress-induced suppression of natural killer cytotoxic activity and/or cancer induction, the countermeasures for Psychophysiological Stress may be invoked.

During occasional Solar flare activity, the crew must retreat to a shielded safe haven for protection against excessive doses of radiation.

Finally, the crewmember must return to earth before the radiation exposure limit is exceeded, natural killer cytotoxic function is markedly reduced, chromosomal aberrations are significantly increased, and/or DNA synthesis of blood lymphocytes is markedly increased.

Related Operationally Important Problems

Infection
Anemia
Psychophysiological Stress

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HISTORICAL BACKGROUND

- RADIATION EXPOSURE
  - ONE OF THE MAJOR EFFECTS OF LOW - LEVEL RADIATION IS CARCINOGENESIS
  - IN THE 85-DAY SKYLAB 4 MISSION, THE MEAN DOSE WAS 7.8 RADS, AND IN EIGHT SPACE SHUTTLE MISSIONS, THE OVERALL MEAN TOTAL DOSE WAS 0.42 RAD
  - TOTAL REPORTED DOSE ABSORBED BY A SOVIET COSMONAUT IN 326 DAYS OF FLIGHT WAS 7.6 RADS
  - THE CREW IRRADIATION LEVEL FOR THE SOVIET SALYUT 6 MISSION (175-DAY) WAS 3.2-5.8 RADS
  - MAJOR SOLAR FLARE PROTON SHOWER: 1000 RADS TOTAL BODY IRRADIATION

CANCER INDUCTION

Presenter:
GERALD TAYLOR / JSC

Date:
DEC. 21, 1989

- **RADIATION EXPOSURE - Continued**

  - ESTIMATED CREW EXPOSURES FOR THE 90-DAY SPACE STATION MISSION RANGE FROM 15-20 RADS

  - THE ABOVE ESTIMATE OF 20 RADS TOTAL (220 MRAD / DAY) NEARLY MATCHES THE RECOMMENDED DAILY LIMIT FOR BONE MARROW, EYE LENS AND SKIN, BUT EXCEEDS THE LIMIT FOR TESTIS ACCORDING TO THE NATIONAL RESEARCH COUNCIL, 1970

CANCER INDUCTION

- SPACE FLIGHT - INDUCED CHROMOSOMAL ABERRATIONS
  - MITOGEN - STIMULATED LYMPHOCYTES WERE ARRESTED AT METAPHASE AND CHROMOSOMES WERE ANALYZED FOR ABNORMALITIES WITH VARIABLE RESULTS IN CREWMEMBERS DURING THE GEMINI, APOLLO AND SKYLAB MISSIONS
  - POSTFLIGHT INCREASES IN CHROMOSOMAL ABERRATIONS WERE SHOWN FOR SOME CREWMEMBERS

CANCER INDUCTION

BIOMEDICAL MONITORI[NG]
AND
COUNTERMEASURES

Presenter: GERALD TAYLOR / JSC

Date: DEC. 21, 1989

- **ATTENUATED NATURAL KILLER CYTOTOXICITY**
  - NATURAL KILLER CYTOTOXICITY IS A PRIMARY HOST DEFENSE MECHANISM AGAINST TUMOR DEVELOPMENT
  - NATURAL KILLER CYTOTOXICITY WAS REDUCED IN THE LONG DURATION SOVIET MISSIONS
  - NATURAL KILLER CYTOTOXIC FUNCTION IS RADIOSENSITIVE

CANCER INDUCTION

Presenter:
GERALD TAYLOR / JSC

Date:
DEC. 21, 1989

- **STRESS FACTORS REDUCE IMMUNITY AND INCREASE CANCER INDUCTION**
  - A NUMBER OF STRESSORS (PSYCHOSOCIAL, PHYSIOLOGICAL AND ENVIRONMENTAL) HAVE BEEN IDENTIFIED DURING SPACEFLIGHT THAT MAY REDUCE NATURAL KILLER CYTOTOXIC ACTIVITY AND INCREASE CANCER INDUCTION
  - OTHER STRESSORS HAVE BEEN SHOWN TO REDUCE NATURAL KILLER CYTOTOXIC ACTIVITY IN BOTH HUMAN AND ANIMAL STUDIES
  - STRESS HAS BEEN SHOWN TO ENHANCE THE INDUCTION AND DEVELOPMENT OF EXPERIMENTAL TUMORS IN RATS AND MICE

CANCER INDUCTION

Presenter: GERALD TAYLOR / JSC

Date: DEC. 21, 1989

SIGNIFICANCE

- INCREASED RISK OF CANCER
- PERMITS THE ESTABLISHMENT OF SAFETY LIMITS FOR RADIATION EXPOSURE BASED ON ITS BIOLOGICAL EFFECTS IN SPACE FOR SUBSEQUENT MISSIONS

CANCER INDUCTION

Presenter: GERALD TAYLOR / JSC

Date: DEC. 21, 1989

RECOMMENDATIONS FOR MONITORING

- MONITOR
  - RADIATION EXPOSURE LEVELS WILL BE RECORDED BY THE ENVIRONMENTAL HEALTH FACILITY AND REPORTED TO BMAC AND HMF
  - GENETIC ABNORMALITIES OF MITOGEN - STIMULATED BLOOD LYMPHOCYTES
    - * CHROMOSOMAL ABERRATIONS
    - * ONCOGENE PRODUCTS
    - * DNA SYNTHESIS (REPAIR)
  - NATURAL KILLER CYTOTOXIC FUNCTION

CANCER INDUCTION

BIOMEDICAL MONITORIN
AND
COUNTERMEASURES

Presenter: GERALD TAYLOR / JSC

Date: DEC. 21, 1989

- **HYPOTHESIZED RESULTS AND SIGNIFICANCE**
  - RADIATION EXPOSURE ABOVE ACCEPTABLE LIMITS MAY INCREASE THE RISK OF CANCER
  - INCREASED NUMBER OF CHROMOSOMAL ABERRATIONS, ONCOGENE PRODUCTS, AND DNA SYNTHESIS (REPAIR) IN MITOGEN - STIMULATED BLOOD LYMPHOCYTES ARE INDICATIVE OF RADIATION DAMAGE AT THE CELLULAR LEVEL THAT MAY INCREASE THE RISK OF CANCER
  - SUPPRESSED NATURAL KILLER CYTOTOXIC FUNCTION IS INDICATIVE OF RADIATION DAMAGE AND/OR ATTENUATED IMMUNITY DURING SPACEFLIGHT AND MAY INCREASE THE RISK OF CANCER

ANTICIPATED COUNTERMEASURES

- ENHANCE NATURAL KILLER CYTOTOXIC FUNCTION WITH CYTOKINES, INTERFERON OR INTERLEUKIN 2, IN ORDER TO INCREASE IMMUNITY TO CANCER CELLS
- MINIMIZE STRESS BY INVOKING THE COUNTERMEASURES FOR PSYCHOPHYSIOLOGICAL STRESS
- RETREAT TO A SHIELDED SAFE HAVEN FOR THE OCCASIONAL GIANT SOLAR PARTICLE EVENT
- RETURN TO EARTH BEFORE RADIATION EXPOSURE LIMIT IS EXCEEDED, NATURAL KILLER CYTOTOXIC FUNCTION IS MARKEDLY REDUCED, CHROMOSOMAL ABERRATIONS ARE INCREASED, AND / OR DNA SYNTHESIS OF BLOOD LYMPHOCYTES IS MARKEDLY INCREASED

CANCER INDUCTION

BIOMEDICAL MONITORING AND COUNTERMEASURES

Presenter: GERALD TAYLOR / JSC

Date: DEC. 21, 1989

RELATED OPERATIONALLY IMPORTANT PROBLEMS

- INFECTION
- ANEMIA
- PSYCHOPHYSIOLOGICAL STRESS

OSTEOPOROSIS AND FRACTURES

Historical Background

Bone demineralization in microgravity closely resembles the pathology of disuse osteoporosis and has the potential to cause both chronic and acute problems, particularly in long duration or repeated missions (FASEB - Bone Demineralization, 1984, p. 1). The major health hazards associated with bone demineralization include extended recovery time of lost bone mass postflight, the possibility that this lost mass is not completely reversible, signs and symptoms of hypercalcemia, risk of kidney stones from hypercalciuria, possible effects of calcification in the soft tissues, and possible increase in the risk of fracture (Schneider, et al., 1989, p. 220).

U.S. and Soviet studies indicate that approximately 0.3 to 0.4% of total body calcium is lost each month during spaceflight. Measurement of os calcis mass indicates that weight bearing bones lose about 5% of their mass per month while non-weight-bearing bones, such as the radius and ulna, show no measurable loss (FASEB - Bone Demineralization, 1984, p. 1). Bone loss appears to be proportional to mission length and ranges from -0.9 to -19.8 percent over periods from 75 to 184 days (Schneider, et al., 1989, p. 214).

It is not apparent whether this loss is completely reversible. The possibility exists that the calcium balance might return to preflight balances before the bone mass lost during spaceflight has been regained, causing irreversible damage to the skeleton (Rambaut and Johnston, 1979). Bone loss appears to be reversible following flights as long as 84 days, but reversibility of bone loss on long duration flights needs to be verified (FASEB - Bone Demineralization, 1984, p. 1). Os calcis mineral content of the Skylab 3 crewmen returned to postflight values by 87 days postflight; however, the os calcis mineral content of two Skylab 4 crewmen had not been regained 95 days postflight. Additionally, os calcis mineral content in the nine crewmembers participating in the Skylab program was significantly lower than in the eight back-up astronauts five years postflight (FASEB - Bone Demineralization, 1984, p. 9).

Extensive ground-based studies by both the U.S. and Soviets have utilized bedrest as a model to predict the amount of mineral that will be lost in microgravity. Although the results of bedrest studies are not identical to those of inflight balance studies, they are reliable and reproducible while offering insight into the mechanisms of bone loss (Schneider, et al., 1989, p. 217).

The Robbins committee report recommends determining the mechanism of bone loss inflight as well as its possible associated complications. The committee's report states that the development and testing of drugs to prevent and moderate bone loss should be made a high priority (Robbins Report, 1988, pp. 46, 49).

The recommendations of the Goldberg committee report include: (1) to understand the basic mechanisms that influence bone demineralization; (2) to understand the basic mechanisms of calcium homeostasis; (3) to determine the relationship between the above two processes; (4) to determine the extent to which the bone demineralization occurs in space is similar to that occurring in various ground-based models; and (5) to continue the development of countermeasures for bone demineralization. In addition, the committee recommends that knowledge on the postflight reversibility of bone loss should be obtained. (Goldberg Report, 1987, pp. 112, 116).

The FASEB report on bone demineralization states that even though the previous levels of mineral loss have not been associated with impaired functional capacities, bone demineralization should be regarded as a significant biomedical problem of space flight (FASEB - Bone Demineralization, 1984, p. 2). The committee recommends the study of pharmacologic, dietary and exercise countermeasures to ameliorate the loss of bone mass.

Recommendations for Monitoring

Appropriate monitoring for bone demineralization inflight would include: (1) plasma levels of vitamin D metabolites, PTH, corticosteroids, and total and ionized calcium; (2) urinary excretion of calcium and hormones; and (3) G.I. absorption and fecal calcium. Pre- and postflight bone density should be measured to determine the amount of bone loss inflight as well as the rate of recovery.

Related Operationally Important Problems

Renal Stones
Increased Muscular Fatigue/Decreased Muscular Strength
Decreased Ability to Emergency Egress

FASEB. Talbot J, Fisher K, editors. *Research Opportunities in Bone Demineralization.* Bethesda: Federation of American Societies for Experimental Biology; NASW 3924, 1985.

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HISTORICAL BACKGROUND

- OS CALCIS MINERAL CONTENT IN THE NINE CREWMEMBERS PARTICIPATING IN THE SKYLAB PROGRAM WAS SIGNIFICANTLY LOWER THAN IN THE EIGHT BACK-UP ASTRONAUTS FIVE YEARS POSTFLIGHT

- TOTAL BODY CALCIUM LOSSES AVERAGE 0.3 TO 0.4% PER MONTH AND OS CALCIS (A WEIGHT-BEARING BONE) LOSSES AVERAGE ABOUT 5% PER MONTH DURING LONG DURATION SPACEFLIGHT

- SOVIET EXPERIENCE INDICATES THAT THE DEGREE OF DEMINERALIZATION OF THE TIBIA DEPENDS PRIMARILY ON THE COMPLETE UTILIZATION OF RECOMMENDED COUNTERMEASURES RATHER THAN ON THE DURATION OF THE FLIGHT ITSELF

OSTEOPOROSIS AND FRACTURES

BIOMEDICAL MONITORING AND COUNTERMEASURES

Presenter: GERALD TAYLOR / JSC

Date: DEC. 21, 1989

SIGNIFICANCE

- IRREVERSIBLE BONE LOSS INCURRED AS A RESULT OF LONG DURATION AND REPEATED SPACE FLIGHTS COULD LEAD TO OSTEOPOROSIS AND FRACTURES

RECOMMENDATIONS FOR MONITORING

- MONITOR
  - PATTERNS AND RATE OF BONE LOSS
  - CALCIUM HOMEOSTASIS
  - REVERSIBILITY OF BONE DEMINERALIZATION

OSTEOPOROSIS AND FRACTURES

Presenter: GERALD TAYLOR / JSC

Date: DEC. 21, 1989

- **HYPOTHESIZED RESULTS AND SIGNIFICANCE**
  - EVIDENCE OF BONE DEMINERALIZATION IN WEIGHT-BEARING BONES AND CHANGES IN PLASMA AND URINE ELECTROLYTE LEVELS AND FECAL CALCIUM
  - BONE DEMINERALIZATION DURING MICROGRAVITY MAY BE IRREVERSIBLE

ANTICIPATED COUNTERMEASURES

- APPROPRIATELY PRESCRIBED EXERCISE
- DIETARY MODIFICATIONS
- PHARMACOLOGIC INTERVENTION (FLUORIDE OR DIPHOSPHATE ANALOGUE, e.g., APD)

RELATED OPERATIONALLY IMPORTANT PROBLEMS

- RENAL STONES
- INCREASED MUSCULAR FATIGUE / DECREASED MUSCULAR STRENGTH
- DECREASED ABILITY TO EMERGENCY EGRESS